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# Resilient Modulus of Freeze-Thaw Affected Granular Soils for Pavement Design and Evaluation

Part 2. Field Validation Tests at Winchendon, Massachusetts, Test Sections

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U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire 03755-1290

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Stress-deformation data for six granular soils ranging from sandy silt to dense-graded crushed stone were obtained from in-situ tests and laboratory tests. Surface deflections were measured in the in-situ tests, with repeated-load plate-bearing and falling-weight deflectometer equipment, when the six granular soils were frozen, thawed, and at various stages of recovery from thaw weakening. The measured deflections were used to judge the validity of procedures developed for laboratory triaxial tests to determine nonlinear resilient moduli of specimens in the frozen, thawed, and recovering states. The validity of the nonlinear resilient moduli, expressed as functions of externally applied stress and moisture tension, was confirmed by using the expressions to calculate surface deflections that were found to compare well with deflections measured in the in-situ tests. The tests on specimens at various stages of recovery are especially significant because they show a strong dependence of the resilient modulus on moisture tension, leading to the conclusion that predictions or in-situ measurements of moisture tension can be used to evaluate expected seasonal variation in the resilient modulus of granular soils.



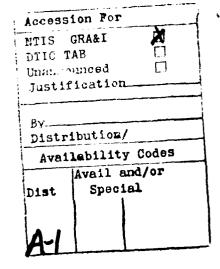
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#### **PREFACE**

This report was prepared by Thaddeus C. Johnson and Diane L. Bentley, Research Civil Engineers, Civil Engineering Research Branch; and David M. Cole, Research Civil Engineer, Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

The study was funded under DA Project 4A762730AT42, Design, Construction and Operations Technology for Cold Regions; Task BS, Base Support; Work Unit 002, Seasonal Change in Strength and Stiffness of Soils and Base Courses. The Federal Highway Administration (FHWA) and the Federal Aviation Administration (FAA) of the Department of Transportation shared equally in the funding, under FHWA Order No. 8-3-0187, Full-scale Field Tests to Evaluate Frost Action Predictive Techniques.

The authors gratefully acknowledge the financial support of the Corps of Engineers, the FHWA and the FAA. The Massachusetts Department of Public Works made available their frost action test site at Winchendon, Massachusetts. The authors were allowed virtually unrestricted use of the site for field testing and data collection, and the Department also provided extensive data on soil properties and other site conditions. Dr. Richard Berg was co-leader of the overall project, along with the senior author, and provided essential field and laboratory data from other phases of the work. Many other persons at CRREL contributed to the study. One of the principal contributors to the work described in this report was Dr. Lynne Irwin, who, while on temporary assignment at CRREL during sabbatical leave from Cornell University, developed NELAPAV, the computer program used in the deflection basin analyses. Other principal contributors were Edwin Chamberlain, who had a major role in the development of the laboratory testing techniques; Glenn Durell, who conducted the resilient modulus testing; and Donald Keller, who conducted the field loading tests. David Carbee, Gregor Fellers, and Jonathan Ingersoll also assisted in the research. This report was technically reviewed by F.H. Sayles of CRREL.





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# Resilient Modulus of Freeze-Thaw Affected Granular Soils for Pavement Design and Evaluation art 2: Field Velidation Tests at Winshender, Massachusetts, Test Section

Part 2: Field Validation Tests at Winchendon, Massachusetts, Test Sections

T.C. JOHNSON, D.L. BENTLEY AND D.M. COLE

#### INTRODUCTION

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The damaging effects of the freeze-thaw cycle on the riding qualities, integrity, and durability of pavements are notorious. In areas of seasonal frost the supporting capacity of subgrade soils and unbound base and subbase materials for roads and airfields can vary drastically through freeze-thaw cycles and the subsequent spring-summer recovery period. In a joint project with the Federal Highway Administration and the Federal Aviation Administration, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has evaluated these fluctuations in material properties for six test soils and developed suitable predictive models. Both laboratory and field tests were conducted.

This report focuses on the underlying cause of problems of premature distress in pavement systems that are susceptible to frost—the reduction of the resilient modulus of subgrade soils and unbound base courses during and following spring thaws. In this context the resilient modulus is conventionally defined as deviator stress divided by resilient-i.e., recoverable-strain. The research results presented in the report are concerned with frost-susceptible granular soils that exhibit little or no cohesion and a high degree of nonlinearity. The research objective was to develop laboratory methods of characterizing the seasonal changes of the resilient modulus of these soils throughout a complete annual cycle. It was considered necessary to conduct field tests to validate the laboratory methods. The field tests and analysis of the data are the subject of this report.

Repeated-load triaxial tests were performed to determine the resilient characteristics of the component materials in experimental paved test sections under conditions simulating those that prevailed during the field tests. The laboratory triaxial tests were performed on soils in the frozen,

thawed, recovering, and recovered conditions. Empirical relationships were then generated by standard statistical techniques to express the resilient modulus  $M_r$  as a function of density, soil moisture tension, and the stresses imposed in the triaxial tests. For frozen soil and for asphalt concrete the temperature is also a key parameter.

Field tests were used to determine the surface deflection response of paved soil test sections under plate loads. Surface deflection basins were measured under loads imposed by a repeated-load plate-bearing (RPB) apparatus and a falling-weight deflectometer (FWD). The tests were performed at critical times between late fall and late spring to characterize the variation in load response throughout the freeze-thaw-recovery cycle

The validity of the laboratory results was then examined by comparing the measured deflection basins with deflection basins calculated for the test section using the expressions for resilient modulus developed from the laboratory tests. In using these expressions, temperatures and moisture tensions measured at the time of each field loading test were applied to evaluate the resilient modulus. Layered elastic analyses of the test sections under the conditions prevailing during each field loading test yielded stresses, strains, and resilient vertical displacements throughout the system; calculated surface deflection basins were thus generated and compared to the deflection basins actually meassured in the field.

The field and laboratory tests were conducted on six soils in test sections constructed by the Massachusetts Department of Public Works in Winchendon, Massachusetts. The results for the six soils are presented here. Detailed procedures, results, and at syses of repeated-load triaxial tests to characterize the asphalt concrete pavement, the six test soils, and the natural sandy gravel subgrade are given by Cole et al. (1986).

#### SAMPLING OF TEST SECTION

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The Winchendon test site, constructed in 1978 by the Massachusetts Department of Public Works, consists of 24 soil test sections (Figs. 1, 2). Twelve different soils are used, each in embankments of two different heights. Six of the higher embankments were used as test sections in this research, each consisting of about 50-90 mm of asphalt concrete and 1.5 m of test soil (either Ikalanian sand, Graves sand, Hart Brothers sand, Hyannis sand, dense-graded stone, or Sibley till) overlying the natural subgrade, a clean gravelly sand (Fig. 3). The water table is about 1.4 m below the pavement surface.

Samples of the asphalt concrete, the test soils, and the natural subgrade were taken in October 1978, before freezing had occurred. Core samples 101.6 mm in diameter were taken from the asphalt pavement. Undisturbed samples of the test soils, except the dense-graded stone, were taken with a double-tube auger. Soil samples were 57.2 mm in

diameter and 152.4 mm long. They were preserved in the split sleeves used in the sampling device, wrapped in polyethylene film to prevent moisture loss, and padded to prevent disturbance during transportation. Bag samples of the natural subgrade material and the test soils were also obtained.

In February 1979, once frost penetration was sufficient, undisturbed samples of frozen soil were taken from the Ikalanian sand, Graves sand, Hart Brothers sand, and Hyannis sand test sections. A single-tube, hollow auger was used. Cores 50.8 mm in diameter and up to 300 mm long were obtained. The Sibley till and dense-graded stone could not be core-drilled because of the presence of many stones. Occasional pebbles in the other sections also caused difficulties. All the core samples were tightly wrapped in polyethylene film and placed in bags with snow to prevent sublimation during transport to the laboratory. The cores were stored in a -7°C environment until trimmed and tested.

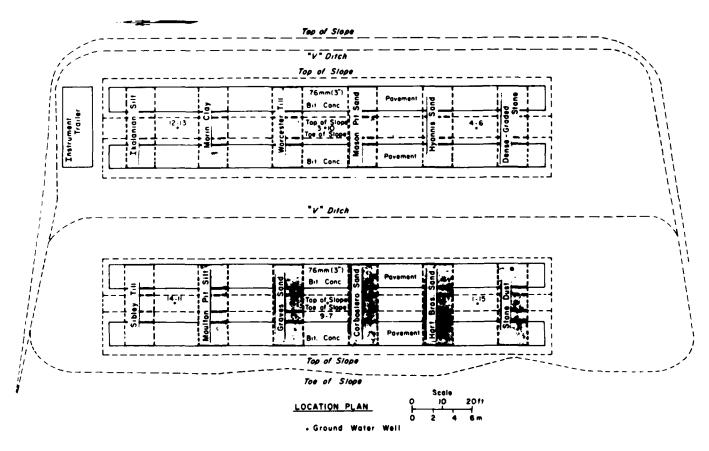
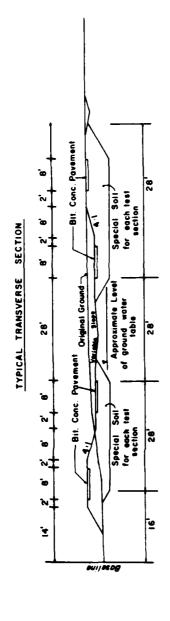


Figure 1. Plan view, Winchendon, Mass., test site.



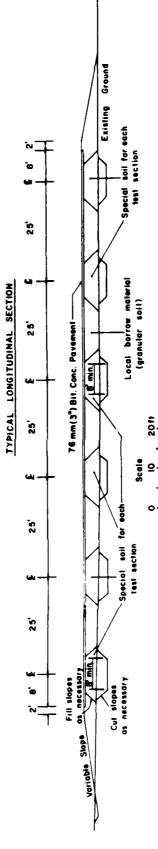


Figure 2. Transverse and longitudinal sections, Winchendon test site.

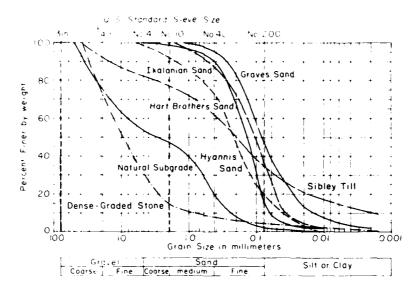


Figure 3. Grain-size distributions of test soils and natural subgrade.

#### LABORATORY TESTS

Laboratory tests were performed to characterize the resilient modulus of the asphalt concrete, the six test soils, and the natural subgrade soil. Detailed test procedures and data analysis are given by Cole et al. (1986). The tests are briefly described here, and the results are summarized, only to the extent necessary to give meaning to the field testing and analyses conducted to validate the laboratory results.

#### Asphalt concrete

Initially, asphalt concrete core specimens 101.6 mm in diameter were tested in repeated indirect tension (diametral compression) at two load durations (0.1 and 1.0 sec) and at temperatures from -10 to +32°F. Cores 50 to 90 mm in length also were cemented together with asphalt emulsion in groups of three to form cylindrical specimens 200-250 mm long and were tested in repeated-load unconfined compression at axial stresses from 69.0 to 241.3 kPa and temperatures from -10 to +39°C. It was desired to simulate the load pulse of each of the two dynamic plate-loading tests used in the field in-situ tests, the RPB and the FWD, so three loading waveforms were used in the laboratory: a 1-sec pulse applied every 3 seconds, which simulates the RPB pulse; a continuous haversine waveform at 1, 4, and 16 Hz according to ASTM D3497-76T; and a 28-ms haversine pulse every 2 seconds that simulates the FWD load pulse.

Multiple linear regression analyses of the results showed that the asphalt concrete resilient modulus  $M_{\rm r}$  is insensitive to the peak amplitude of the stress. For the slower RPB waveform,  $M_{\rm r}$  is a function of the temperature only, while for haversine loading  $M_{\rm r}$  is a function of temperature and frequency (Table 1). Representative results showing relationships generated by the regression equations are given in Figure 4.

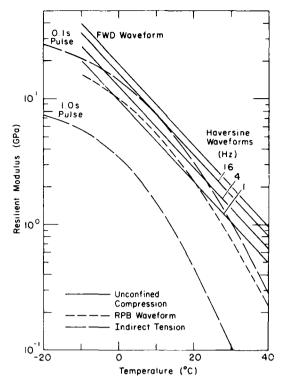
#### Natural subgrade material

Since the natural gravelly sand subgrade soil existing beneath the test sections at Winchendon does not undergo freezing and thawing, it was tested only in the nonfrozen condition. Specimens measuring 152.4 mm in diameter and 381.0 mm long were compacted to about 2.00 mg/m3, the estimated in-situ dry density. Once placed in a triaxial cell, each specimen was vacuum-saturated and then subjected to various combinations of static axial and confining stresses as given in Table 2. Drainage was permitted each time the static stress level was increased, though the reservoir level was maintained at the top of the sample. A deviator stress was then applied repeatedly under the waveforms of the RPB and FWD load pulses, while permitting no further drainage.

A stepwise multiple linear regression analysis was performed on the results. The resilient modulus was expressed as a function of either of two stress invariant parameters. Initially the bulk stress,  $\theta$ , or first stress invariant  $J_1 = \sigma_1 + \sigma_2 + \sigma_3$  was used, in accordance with conventional prac-

Table 1. Results of regression analysis.

Asphalt concrete  RPB	Asphalt concrete  RPB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = \exp[9.204-5.552 \times 10^{-17} - 9.744 \times 10^{-17}]$ BRB $M_{t}(MPa) = 20.74 f_{t}(p^{0.743})$ BR			Table 1. Results of regression analysis	•		Std.
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Haversine $M_{c}(MPa) = \exp[9.183-7.4 \times 10^{-2}T]^{0.1777}$ 158 0.81 0.4 $M_{c}(MPa) = \exp[9.429-7.47 \times 10^{-2}T]$ 65 0.67 0.2 $M_{c}(MPa) = \exp[9.429-7.47 \times 10^{-2}T]$ 65 0.66 0.67 0.67 0.2 $M_{c}(MPa) = \exp[9.429-7.47 \times 10^{-2}T]$ 65 0.66 0.68 0.76 0.2 $M_{c}(MPa) = \exp[9.429-7.47 \times 10^{-2}T]$ 65 0.66 0.88 0.3 $M_{c}(MPa) = \exp[9.670-1.0314T-0.0708T^{-1}(\tau_{cot}/\sigma_{o})^{-0.42}]$ 56 0.88 0.3 $M_{c}(MPa) = \exp[9.670-1.0314T-0.0708T^{-1}(\tau_{cot}/\sigma_{o})^{-0.42}]$ 56 0.88 0.3 $M_{c}(MPa) = \exp[9.670-1.0314T-0.0708T^{-1}(\tau_{cot}/\sigma_{o})^{-0.42}]$ 186 0.76 0.2 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 73 0.95 0.4 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 74 0.94 186 0.67 0.2 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 75 0.95 0.91 0.3 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 76 0.94 186 0.89 0.1 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 77 0.92 0.71 0.2 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 78 0.95 0.91 0.3 $M_{c}(MPa) = \exp[-1.19 \times 10^{-1.19}T]$ 79 0.95 0.91 0.91 0.91 0.91 0.91 0.91 0.91 0.91	Haversine $M_{ij}(MPa) = \exp[9.183-7.47 \times 10^{-7}]^{0.177}$ 158 0.81 0.4 FWD $M_{ij}(MPa) = \exp[9.429-7.47 \times 10^{-7}]^{0.177}$ 65 0.67 0.2 Natural subgrade  RPB and FWD $M_{ij}(MPa) = \exp[9.183-7.47 \times 10^{-7}]^{0.177}$ 65 0.66 0.2 Grave sand  Frozen RPB $M_{ij}(MPa) = \exp[9.670-1.0314T-0.0708T^{1}](\tau_{co}/\sigma_o)^{-0.42}$ 56 0.88 0.3 RPB $M_{ij}(MPa) = \exp[9.677-1.0314T-0.0708T^{1}](\tau_{co}/\sigma_o)^{-0.42}$ 56 0.88 0.3 RPB $M_{ij}(MPa) = \exp[9.677-1.0314T-0.0708T^{1}](\tau_{co}/\sigma_o)^{-0.42}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 2.139 \times 10^{-7}(ij)^{1.793}$ 73 0.95 0.4 186 0.76 0.2 FWD $M_{ij}(MPa) = 2.139 \times 10^{-7}(ij)^{1.793}$ 722 0.71 0.2 22 0.71 0.2 FWD $M_{ij}(MPa) = 2.139 \times 10^{-7}(ij)^{1.793}$ 7.60 $^{0.643}$ 186 0.89 0.1 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 7.70 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 7.70 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 7.70 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 7.70 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 7.70 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 197 $^{0.943}$ 186 0.76 0.2 FWD $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 197 $^{0.943}$ 19.0 0.3 Recovered RPB $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 19.0 $^{0.943}$ 19.0 0.3 RPB $M_{ij}(MPa) = 4.09 \times 10^{-7}$ 19.0 $^{0.943}$ 19.0 0.3 RPB $M_{ij}(MPa) = 8.129 \times 10^{-7} \times 10^{-7}$ 19.1 $^{0.943} \times 10^{-7}$ 19.0 0.3 RPB $M_{ij}(MPa) = 8.129 \times 10^{-7} \times 10^{-7}$ 19.1 $^{0.943} \times 10^{-7}$ 19.0 0.4 0.3 RPB $M_{ij}(MPa) = 8.129 \times 10^{-7} \times 10^{-7}$ 19.1 $^{0.943} \times 10^{-7}$ 19.0 0.4 0.3 RPB $M_{ij}(MPa) = 8.09 \times 10^{-7} \times 10^{-7}$ 19.0 0.4 0.3 RPB $M_{ij}(MPa) = 8.09 \times 10^{-7} \times 10^{-7}$ 19.0 0.4 0.3 RPB $M_{ij}(MPa) = 8.09 \times 10^{-7} \times 10^{-7} \times 10^{-7} \times 10^{-7}$ 19.0 0.9 0.2 0.6 RPB $M_{ij}(MPa) = 8.09 \times 10^{-7} $	Asphalt concrete					
Natural subgrade  RPB and FWD $M_{i}(MPa) = 8.829 f_{i}(o)^{0.00}$ $RPB$ and FWD $M_{i}(MPa) = 8.829 f_{i}(o)^{0.00}$ $RPB$ and FWD $M_{i}(MPa) = 20.74 f_{i}(o)^{0.00}$ $RPB$ and FWD $M_{i}(MPa) = 20.74 f_{i}(o)^{0.00}$ $RPB$ $RPB$ $M_{i}(MPa) = 30.1(w_{i}/w_{i})^{1.19}$ $RPB$ $M_{i}(MPa) = 39.1(w_{i}/w_{i})^{1.19}$ $RPB$ $M_{i}(MPa) = 2.139 \times 10^{10} f_{i}(0)^{1.219} f_{i}(0)^{0.01}$ $RPB$ $M_{i}(MPa) = 9.27 \times 10^{10} f_{i}(0)^{1.219} f_{i}(0)^{0.01}$ $RPB$ $M_{i}(MPa) = 4.89 f_{i}(0)^{0.00}$ $RPB$ $M_{i}(MPa) = 4.80 f_{i}(0)^{0.00}$ $RPB$ $M_{i}(MPa) = 8.129 \times 10^{10} f_{i}(0)^{1.139} f_{i}(0)^{0.412}$ $RPB$ $M_{i}(MPa) = 8.129 \times 10^{10} f_{i}(0)^{1.139} f_{i}(0)^{0.412}$ $RPB$ $M_{i}(MPa) = 8.129 \times 10^{10} f_{i}(0)^{1.139} f_{i}(0)^{0.412}$ $RPB$ $M_{i}(MPa) = 3.021 \times 10^{10} f_{i}(0)^{1.139} f_{i}(0)^{0.139}$	Natural subgrade  RPB and FWD $M_{c}(MPa) = 8.829 f_{c}(o^{0.20} ^{100} )$ $RPB$ and FWD $M_{c}(MPa) = 20.74 f_{c}(o^{0.20} )$ $M_{c}(MPa) = 8.829 f_{c}(o^{0.20} )$ $M_{c}(MPa) = 9.20 f_{c}(o^{0.20} )$ $M_{c}(O^{0.20} )$ $M_{c}(O^{0.2$		RPB	•,	85	0.97	0.28
Natural subgrade  RPB and FWD  RPB and FWD  RPB and FWD  RPB M(MPa) = $8.829 f_1(\sigma)^{0.708}$ 65 0.67 0.2  Graves sand  Frozen  RPB  M(MPa) = $20.74 f_1(\sigma)^{0.332}$ 65 0.76 0.2  Graves sand  Frozen  RPB  M(MPa) = $39.1(w_1/w_1)^{-1.90}$ FWD  M(MPa) = $39.1(w_1/w_1)^{-1.90}$ FWD  M(MPa) = $39.1(w_1/w_1)^{-1.90}$ FWD  M(MPa) = $39.1(w_1/w_1)^{-1.90}$ RPB  M(MPa) = $39.14(w_1/w_1)^{-1.90}$ RPB  M(MPa) = $39.14(w_1/w_1)^{-1.90}$ RPB  M(MPa) = $39.12(w_1/w_1)^{-1.90} f_1(\sigma)^{0.402}$ RPB  M(MPa) = $30.14(w_1/w_1)^{-1.90} f_1(\sigma)^{0.402}$ RPB  M(MPa) = $30.14(w_1/w_1)^{-1.90} f_1(\sigma)^{0.402}$ RPB  M(MPa) = $30.14(w_1/w_1)^{-1.90} f_1(\sigma)^{0.402}$ Recovered  RPB  M(MPa) = $4.80 f_1(\sigma)^{0.400}$ RPB  M(MPa) = $4.80 f_1(\sigma)^{0.400}$ RPB  M(MPa) = $4.80 f_1(\sigma)^{0.400}$ RPB  M(M(MPa) = $4.80 f_1(\sigma)^{0.400}$ RPB  M(M(MPa) = $4.80 f_1(\sigma)^{0.400}$ RPB  M(M(MPa) = $3.02 \times 10^{-1} f_1(\sigma)^{0.400}$ RPB  M(M(MPa)	Natural subgrade  RPB and FWD  RPB and FWD  RPB and FWD  RPB and FWD  RPB M(MPa) = $8.829 f_1(\sigma^{0.708})$ 65 0.67 0.2  Graves sand  Frozen  RPB  M(MPa) = $20.74 f_1(\sigma^{0.708})$ RPB  M(MPa) = $32.14 (w_1/w_1)^{-1.90}$ Frozen  RPB  M(MPa) = $32.14 (w_1/w_1)^{-1.90}$ FWD  M(MPa) = $32.14 (w_1/w_1)^{-1.90}$ RPB  M(MPa) = $3.14 (w_1/w_1)^{-1.90}$ RPB  M(MPa) = $3.44 (w_1/w_1)^{-1.90}$ RPB  M(M(MPa) = $3.44 (w_1/w_1)^{-1.90}$ RPB  M(MPa) = $3.44 (w_1/w_1)^{-1.90}$ RPB  M(M(MPa) = $3.44 (w_1/w_1)$			• • • • • • • • • • • • • • • • • • • •	158	0.81	0.44
RPB and FWD $M_{1}(MPa) = 8.829 f_{1}(p^{3} - 32)$ 65 0.67 0.2 Graves sand  Frozen RPB $M_{1}(MPa) = 20.74 f_{1}(p^{3} - 32)$ 56 0.88 0.20  Frozen RPB $M_{2}(MPa) = 20.74 f_{1}(p^{3} - 32)$ 56 0.88 0.20  FVD $M_{3}(MPa) = 39.1(w_{2}w_{3}^{3} - 1.03)$ 73 0.95 0.41  Thawed RPB $M_{1}(MPa) = 39.1(w_{2}w_{3}^{3} - 1.03)$ 186 0.76 0.20  FWD $M_{1}(MPa) = 39.1(w_{2}w_{3}^{3} - 1.03)$ 186 0.76 0.20  RPB $M_{2}(MPa) = 39.1(w_{2}w_{3}^{3} - 1.03)$ 186 0.76 0.20  RPB $M_{1}(MPa) = 39.1(w_{2}w_{3}^{3} - 1.03)$ 186 0.76 0.20  RPB $M_{1}(MPa) = 4.80 f_{1}(p^{3} - 1.03)$ 186 0.89 0.11  FWD $M_{2}(MPa) = 1.47 \times 10^{7} f_{1}(p^{3} - 1.03)$ 196 0.36 0.77 0.10  Recovered RPB $M_{2}(MPa) = 6.88 f_{1}(p^{3} - 1.03)$ 197 $f_{1}(p^{3} - 1.03)$ 197 (2.20) 19.00  Recovered RPB $M_{2}(MPa) = 6.89 f_{1}(p^{3} - 1.03)$ 19.00  RPB $M_{2}(MPa) = 6.89 f_{1}(p^{3} - 1.03)$ 19.00  RPB $M_{2}(MPa) = 8.64 (w_{2}w_{3} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 8.61 (w_{2}w_{3} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 8.64 (w_{2}w_{3} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 8.129 \times 10^{2} f_{2}(p^{2} - 1.03)$ 19.00  RPB $M_{2}(MPa) = 8.129 \times 10^{2} f_{2}(p^{2} - 1.03)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1.03)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1.13)$ 19.00  RPB $M_{2}(MPa) = 3.02 \times 10^{2} f_{2}(p^{2} - 1$	RPB and FWD $M_{ij}(MPa) = 8.829 f_{ij} f_{ij}^{D \times M}$ 65 0.67 0.2 Graves sand  Frozen RPB $M_{ij}(MPa) = 2.07.4 f_{ij} f_{ij}^{D \times M}$ 56 0.88 0.65 0.76 0.2 Graves sand  Frozen RPB $M_{ij}(MPa) = 39.1 (w_{ij}^{D \times M})^{1.79}$ 55 0.91 0.5 FWD $M_{ij}(MPa) = 39.1 (w_{ij}^{D \times M})^{1.79}$ 73 0.95 0.4 RPB $M_{ij}(MPa) = 39.1 (w_{ij}^{D \times M})^{1.79}$ 73 0.95 0.4 RPB $M_{ij}(MPa) = 39.1 (w_{ij}^{D \times M})^{1.79}$ 73 0.95 0.4 RPB $M_{ij}(MPa) = 39.1 (w_{ij}^{D \times M})^{1.79}$ 722 0.71 0.2 RPB $M_{ij}(MPa) = 2.139 \times 10^{-1} f_{ij}^{D \times M} f_{ij}^{D \times M}$ 186 0.76 0.2 RPB $M_{ij}(MPa) = 1.47 \times 10^{-7} f_{ij}^{D \times M} f_{ij}^{D \times M}$ 186 0.89 0.17 FWD $M_{ij}(MPa) = 1.47 \times 10^{-7} f_{ij}^{D \times M} f_{ij}^{D \times M}$ 36 0.76 0.2 RPB $M_{ij}(MPa) = 4.89 f_{ij}^{D \times M} f_{ij}^{D \times M}$ 36 0.76 0.2 RPB $M_{ij}(MPa) = 4.89 f_{ij}^{D \times M} f_{ij}^{D \times M} f_{ij}^{D \times M}$ 36 0.76 0.2 RPB $M_{ij}(MPa) = 4.89 f_{ij}^{D \times M} f_{ij}^{D \times M} f_{ij}^{D \times M} f_{ij}^{D \times M}$ 37 0.1 Reaction as sand  Frozen RPB $M_{ij}(MPa) = 86.4 w_{ij}^{M \times M} f_{ij}^{D \times M} $	N		$M_{\rm f}({\rm MPa}) = \exp[9.429-7.47\times 10^{-2}T]$	_	_	_
RPB and FWD $M_1(MPa) = 20.74 f_1(o)^{0.132}$ Graves sand  Frozen RPB $M_1(MPa) = \exp(9.677-1.0314T-0.0708T^*)(\tau_{eq}/\sigma_o)^{-0.432}$ So $M_1(MPa) = \exp(9.677-1.0314T-0.0708T^*)(\tau_{eq}/\sigma_o)^{-0.432}$ FWD $M_1(MPa) = 32.14(w_1/w_1)^{-1.79}$ FWD $M_1(MPa) = 32.14(w_1/w_1)^{-1.79}$ FWD $M_1(MPa) = 32.14(w_1/w_1)^{-1.79}$ FWD $M_1(MPa) = 2.139 \times 10^n f_1(o)^{-2.29} f_1(o)^{0.432}$ RPB $M_1(MPa) = 2.139 \times 10^n f_1(o)^{-2.29} f_1(o)^{0.432}$ RPB $M_1(MPa) = 0.68 \times 10^n f_1(o)^{-2.294} f_1(o)^{0.432}$ Recovered RPB $M_1(MPa) = 6.68 \times 10^n f_1(o)^{-2.294} f_1(o)^{0.414}$ Recovered RPB $M_1(MPa) = 6.89 f_1(o)^{0.414}$ RPB $M_1(MPa) = 8.129 \times 10^n f_1(o)^{-1.29} f_1(o)^{0.419}$ RPB $M_1(MPa) = 8.129 \times 10^n f_1(o)^{-1.29} f_1(o)^{0.419}$ RPB $M_1(MPa) = 3.021 \times 10^n f_1(o)^{0.419}$ RPB $M_1(MPa) = 3.021 \times 10^n f_1(o)^{0.419}$ RPB $M_1(MPa) = 3.021 \times 10^n f_1(o)^{0.419}$ RPB $M_1(MPa) = 3.02$	Graves sand Frozen RPB $M_{r}(MPa) = 20.74 f_{r}(g)^{0.312}$ 65 0.76 0.2 Graves sand Frozen RPB $M_{r}(MPa) = \exp(9.677-1.0314T-0.0708T^{2})(\tau_{req}/\sigma_{0})^{0.642}$ 56 0.88 0.3 FeVD $M_{r}(MPa) = 39.1(w_{r}/w_{r})^{1.79}$ 95 0.91 0.95 0.4 Thawed RPB $M_{r}(MPa) = 39.1(w_{r}/w_{r})^{1.69}$ 77 0.95 0.4 Thawed RPB $M_{r}(MPa) = 31.14(w_{r}/w_{r})^{1.69}$ 186 0.76 0.2 RPB $M_{r}(MPa) = 5.68 \times 10^{9} f_{r}(p)^{2.209} f_{r}(g)^{6.407}$ 222 0.71 0.2 RPB $M_{r}(MPa) = 5.68 \times 10^{9} f_{r}(p)^{2.209} f_{r}(g)^{6.407}$ 222 0.86 0.87 0.1 Recovered RPB $M_{r}(MPa) = 6.89 f_{r}(g)^{6.904}$ 36 0.76 0.2 RPB $M_{r}(MPa) = 8.18 f_{r}(g)^{6.904}$ 36 0.76 0.2 RPB $M_{r}(MPa) = 8.18 f_{r}(g)^{6.904}$ 36 0.76 0.2 RPB $M_{r}(MPa) = 8.18 f_{r}(g)^{6.904}$ 37 0.9 0.3 RPB $M_{r}(MPa) = 8.18 f_{r}(g)^{6.904}$ 37 0.9 0.3 RPB $M_{r}(MPa) = 8.129 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.129}$ 87 0.92 0.7 Thawed RPB $M_{r}(MPa) = 8.129 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.129}$ 19 0.84 0.3 RPB $M_{r}(MPa) = 9.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(p)^{1.208} f_{r}(g)^{9.402}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(g)^{9.208} f_{r}(g)^{9.402}$ 119 0.84 0.2 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(g)^{9.208} f_{r}(g)^{9.402}$ 119 0.84 0.2 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(g)^{9.208} f_{r}(g)^{9.408}$ 119 0.85 0.88 0.88 0.2 RPB $M_{r}(MPa) = 3.021 \times 10^{9} f_{r}(g)^{9.208} f_{r}(g)^{9.408}$ 119 0.84 0.2 RPB $M_{r}(MPa)$	•		M (MDa) = 9.830 f (a)0.708	45	0.67	0.3
Frozen RPB $M_{t}(MPa) = \exp(9.677-1.0314T-0.0708T^{3})(\tau_{eqt}/\sigma_{0})^{-0.442}$ 56 0.88 0.3 PF Ozen RPB $M_{t}(MPa) = 39.1(w_{e}/w_{t})^{-1.79}$ 95 0.91 0.5 FWD $M_{t}(MPa) = 32.14(w_{e}/w_{t})^{-1.79}$ 95 0.91 0.5 FWD $M_{t}(MPa) = 32.14(w_{e}/w_{t})^{-1.79}$ 186 0.67 0.2 FWD $M_{t}(MPa) = 2.139 \times 10^{17}(\psi^{3})^{-2.79}f_{t}(\sigma)^{0.402}$ 186 0.76 0.2 FWD $M_{t}(MPa) = 9.27 \times 10^{17}(\psi^{3})^{-2.79}f_{t}(\sigma)^{0.402}$ 186 0.89 0.1 0.5 FWD $M_{t}(MPa) = 1.47 \times 10^{17}(\psi^{3})^{-2.79}f_{t}(\sigma)^{0.412}$ 222 0.86 0.1 FWD $M_{t}(MPa) = 1.47 \times 10^{17}(\psi^{3})^{-2.79}f_{t}(\sigma)^{0.413}$ 222 0.86 0.1 Recovered RPB $M_{t}(MPa) = 1.47 \times 10^{17}(\psi^{3})^{-2.79}f_{t}(\sigma)^{0.413}$ 36 0.87 0.1 Halanian sand Frozen RPB $M_{t}(MPa) = 4.80f_{t}(\sigma)^{0.416}f_{t}(\sigma)^{0.416}f_{t}(\sigma)^{0.413}$ 36 0.87 0.1 Thawed RPB $M_{t}(MPa) = 8.64(w_{e}/w_{e})^{-1.23}$ 87 0.92 0.3 PF 0.92 0.4 RPB $M_{t}(MPa) = 8.64(w_{e}/w_{e})^{-1.23}$ 87 0.92 0.7 PF 0.8378)w + (0.04416)w^{1}[\tau_{cost}/\sigma_{0}]^{-0.922} 119 0.84 0.3 RPB $M_{t}(MPa) = 3.021 \times 10^{17}(\psi^{3})^{-3.26}f_{t}(\gamma)^{11.59}f_{t}(\sigma)^{0.492}$ 119 0.89 0.2 RPB $M_{t}(MPa) = 3.021 \times 10^{17}(\psi^{3})^{-3.26}f_{t}(\gamma)^{11.59}f_{t}(\sigma)^{0.492}$ 119 0.89 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{17}(\psi^{3})^{-3.26}f_{t}(\gamma)^{11.59}f_{t}(\sigma)^{0.492}$ 38 0.84 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{17}(w_{e})^{-3.26}f_{t}(\gamma)^{11.59}f_{t}(\sigma)^{0.492}$ 38 0.89 0.9 PF 0.	Frozen RPB $M_{t}(MPa) = \exp(9.677-1.03147-0.0708T^{*})(\tau_{eq}/\sigma_{0})^{-0.441}$ 56 0.88 0.3 Prozen RPB $M_{t}(MPa) = 39.1(w_{e}/w_{t})^{-1.79}$ 95 0.91 0.5 FWD $M_{t}(MPa) = 32.14(w_{e}/w_{t})^{-1.79}$ 95 0.91 0.5 FWD $M_{t}(MPa) = 2.139 \times 10^{-7}(ty)^{-1.297} f_{t}(\sigma)^{0.402}$ 186 0.76 0.2 FWD $M_{t}(MPa) = 2.139 \times 10^{-7}(ty)^{-1.297} f_{t}(\sigma)^{0.402}$ 186 0.76 0.2 FWD $M_{t}(MPa) = 9.27 \times 10^{-7}(ty)^{-2.294} f_{t}(\sigma)^{0.412}$ 1222 0.86 0.1 FWD $M_{t}(MPa) = 1.47 \times 10^{-7}(ty)^{-2.294} f_{t}(\sigma)^{0.413}$ 2222 0.86 0.1 Recovered RPB $M_{t}(MPa) = 6.89 \times 10^{-7}(ty)^{-2.294} f_{t}(\sigma)^{0.413}$ 36 0.76 0.2 RPB $M_{t}(MPa) = 4.80 f_{t}(\sigma)^{0.413}$ 36 0.76 0.2 RPB $M_{t}(MPa) = 4.80 f_{t}(\sigma)^{0.413}$ 36 0.76 0.1 Recovered RPB $M_{t}(MPa) = 8.64 (w_{e}/w_{e})^{-1.29}$ 87 0.92 0.3 $+ (0.04416) w^{+}[t_{cos}/\sigma_{0}]^{-0.3242}$ 87 0.92 0.3 RPB $M_{t}(MPa) = 8.64 (w_{e}/w_{e})^{-1.29}$ 87 0.92 1.9 0.90 0.3 Proceed RPB $M_{t}(MPa) = 8.64 (w_{e}/w_{e})^{-1.29}$ 87 0.92 0.1 Proceed RPB $M_{t}(MPa) = 3.021 \times 10^{-7}(ty)^{-1.396} f_{t}(\gamma)^{11.291} f_{t}(\sigma)^{0.402}$ 119 0.84 0.3 RPB $M_{t}(MPa) = 3.021 \times 10^{-7}(ty)^{-1.396} f_{t}(\gamma)^{11.291} f_{t}(\sigma)^{0.402}$ 119 0.89 0.2 Recovered RPB $M_{t}(MPa) = 3.021 \times 10^{-7}(ty)^{-1.396} f_{t}(\gamma)^{11.291} f_{t}(\sigma)^{0.402}$ 318 0.84 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{-7}(ty)^{-1.396} f_{t}(\sigma)^{0.402}$ 318 0.84 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{-7}(ty)^{-1.396} f_{t}(\sigma)^{0.402}$ 318 0.84 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{-7}(w_{e}/w_{e}/w_{e})^{-1.79}$ 88 0.95 0.4 RPB $M_{t}(MPa) = 4.085 \times 10^{-7}(ty)^{-1.296} f_{t}(\sigma)^{0.402}$ 318 0.96 0.4 RPB $M_{t}(MPa) = 4.085 \times 10^{-7}(t_{e}/w_{$			•••			
Frozen RPB $M_{1}(MPa) = \exp(9.677-1.0314T-0.0708T^{1})(\tau_{cm}/\sigma_{0})^{1.064}$ 56 0.88 0.3 RPB $M_{1}(MPa) = 32.14(m_{1}/m_{1})^{1.06}$ 79 50.91 0.5 0.91 0.5 0.91 0.5 0.91 0.5 0.91 0.5 0.91 0.7 0.91 0.91 0.91 0.91 0.91 0.91 0.91 0.91	Frozen RPB $M_{i}(MPa) = \exp(9.677-1.03147-0.0708T^{2})(\tau_{em}/\sigma_{g})^{-0.462}$ 56 0.88 0.3 RPB $M_{i}(MPa) = 32.14(\omega_{i}/\omega_{i})^{-1.79}$ 95 0.91 0.4 Thawed RPB $M_{i}(MPa) = 32.14(\omega_{i}/\omega_{i})^{-1.99}$ 73 0.95 0.4 Thawed RPB $M_{i}(MPa) = 2.139 \times 10^{6} f(\psi)^{2.1293} f(\sigma)^{0.462}$ 186 0.76 0.2 RPB $M_{i}(MPa) = 6.68 \times 10^{9} f(\psi)^{2.1293} f(\sigma)^{0.462}$ 186 0.76 0.2 RPB $M_{i}(MPa) = 6.68 \times 10^{9} f(\psi)^{2.1293} f(\sigma)^{0.462}$ 186 0.76 0.2 RPB $M_{i}(MPa) = 6.68 \times 10^{9} f(\psi)^{2.129} f(\sigma)^{0.461}$ 1222 0.86 0.89 0.1 FWD $M_{i}(MPa) = 6.89 f(\sigma)^{0.461}$ 36 0.76 0.2 RPB $M_{i}(MPa) = 4.80 f_{i}(\sigma)^{0.464}$ 37 0.92 0.7 Thawed RPB $M_{i}(MPa) = 8.129 \times 10^{6} f(\psi)^{2.129} f(\sigma)^{0.462}$ 87 0.92 0.7 Thawed RPB $M_{i}(MPa) = 8.129 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.128} f(\tau)^{0.464}$ 119 0.89 0.8 0.8 RPB $M_{i}(MPa) = 3.021 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.128} f(\tau)^{0.464}$ 119 0.89 0.8 0.8 RPB $M_{i}(MPa) = 3.021 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.128} f(\tau)^{0.464}$ 119 0.89 0.8 0.8 RPB $M_{i}(MPa) = 3.081 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.462}$ 38 0.84 0.2 RPB $M_{i}(MPa) = 3.081 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.462}$ 38 0.84 0.2 RPB $M_{i}(MPa) = 4.085 \times 10^{6} f(\psi)^{2.129} f(\tau)^{0.462} f(\psi)^{0.462}$ 38 0.85 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9		D and I WD	$m_{\Gamma}(m, \alpha) = 20.74 f_2(0)$	05	0.70	0.2
RPB $M_{1}(MPa) = 39.1(w_{1}/w_{1}^{1.79}) = 95 0.91 0.3$ FWD $M_{2}(MPa) = 2.139 \times 10^{12} f(w_{1}/w_{2}^{1.79}) = 186 0.76 0.2$ FWD $M_{3}(MPa) = 2.139 \times 10^{12} f(\psi_{1}^{1.79}) f(x_{1}/w_{2}/w_{3}^{1.79}) = 122 0.71 0.2$ FWD $M_{4}(MPa) = 2.139 \times 10^{12} f(\psi_{1}/w_{2}/w_{3}^{1.79}) f(x_{1}/w_{3}/w_{3}^{1.79}) = 186 0.76 0.2$ RPB $M_{4}(MPa) = 1.47 \times 10^{12} f(\psi_{1}/w_{3}/w_{3}^{1.79}) = 186 0.76 0.2$ RPB $M_{4}(MPa) = 1.47 \times 10^{12} f(\psi_{1}/w_{3}/w_{3}^{1.79}) = 136 0.76 0.2$ Recovered RPB $M_{4}(MPa) = 6.89 f(x_{1}/w_{3}/w_{3}^{1.79}) = 136 0.87 0.10$ Recovered RPB $M_{4}(MPa) = 6.89 f(x_{1}/w_{3}/w_{3}^{1.79}) = 136 0.87 0.10$ RPB $M_{4}(MPa) = 6.89 f(x_{1}/w_{3}/w_{3}^{1.79}) = 136 0.878) w + (0.04416) w^{1} (r_{ee}/r_{e_{3}}/w_{3}/w_{3}^{1.79}) = 136 0.87 0.11$ RPB $M_{4}(MPa) = 8.64 (w_{e}/w_{e}/w_{3}^{1.79}) = 136 0.87 0.12$ Thawed RPB $M_{4}(MPa) = 8.64 (w_{e}/w_{e}/w_{3}^{1.79}) = 137 0.92 0.7$ Recovered RPB $M_{4}(MPa) = 3.021 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 136 f(x_{1}/w_{3}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.021 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.569 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.80 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.031 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.88 0.2$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.89 0.2$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.89 0.2$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.89 0.2$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.99 0.92 0.6$ FWD $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.99 0.92 0.6$ FWD $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.99 0.92 0.6$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.99 0.92 0.6$ RPB $M_{4}(MPa) = 3.081 \times 10^{12} f(\psi_{1}/w_{3}^{1.79}) = 138 0.99 0.92 0.99 0.92 0.99 0.99 0.99 0.99$	RPB		RPB	$M_r(\text{MPa}) = \exp(9.677 - 1.0314T - 0.0708T^2)(\tau_{cost}/\sigma_0)^{-0.68}$	<sup>2</sup> 56	0.88	0.3
Thawed RPB $M_{1}(MPa) = 2.139 \times 10^{4} f(\psi)^{2.732} f_{1}(\sigma)^{0.42}$ 186 0.76 0.2 FWD $M_{1}(MPa) = 9.27 \times 10^{4} f(\psi)^{2.733} f_{1}(\sigma)^{0.42}$ 122 0.71 0.2 RPB $M_{1}(MPa) = 9.27 \times 10^{4} f(\psi)^{2.248} f_{1}(\sigma)^{0.44}$ 186 0.89 0.1 FWD $M_{1}(MPa) = 1.47 \times 10^{4} f(\psi)^{2.248} f_{1}(\sigma)^{0.44}$ 186 0.89 0.1 FWD $M_{1}(MPa) = 1.47 \times 10^{4} f(\psi)^{2.733} f_{1}(\sigma)^{0.41}$ 222 0.86 0.1 Recovered RPB $M_{1}(MPa) = 1.480 f_{1}(\sigma)^{0.448}$ 36 0.76 0.2 RPB $M_{1}(MPa) = 1.480 f_{1}(\sigma)^{0.448}$ 36 0.76 0.2 RPB $M_{1}(MPa) = 1.89 f_{1}(\sigma)^{0.448}$ 37 0.0 S.77 0.1 FWD $M_{1}(T_{coc}/\sigma_{o})^{-0.342}$ 87 0.92 0.7 Thawed RPB $M_{1}(MPa) = 8.129 \times 10^{4} f(\sigma)^{0.1157} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.138} f_{1}(\gamma)^{11.548} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{11.548} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 0.5 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 0.5 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 0.5 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\sigma)^{0.442}$ 119 0.89 0.90 0.5 0.6 RPB $M_{1}(MPa) = 3.021 \times 10^{4} f(\psi)^{2.318} f_{1}(\phi)^{0.442} f_{1}(\phi)^{0.442}$ 119 0.89 0.90 0.90 0.90 0.90 0.90 0.90 0.9	Thawed RPB $M_{1}(MPa) = 2.139 \times 10^{6} f_{1}(y)^{2.132} f_{1}(\phi)^{0.452}$ 186 0.76 0.2 FWD $M_{1}(MPa) = 9.27 \times 10^{7} f_{1}(\psi)^{2.06} f_{1}(\phi)^{0.452}$ 222 0.71 0.2 RPB $M_{2}(MPa) = 6.68 \times 10^{7} f_{2}(\phi)^{2.464}$ 186 0.89 0.1 FWD $M_{2}(MPa) = 6.68 \times 10^{7} f_{2}(\phi)^{2.464} f_{2}(\phi)^{0.413}$ 222 0.86 0.1 Recovered RPB $M_{1}(MPa) = 1.47 \times 10^{9} f_{1}(\phi)^{2.213} f_{1}(\phi)^{0.413}$ 36 0.76 0.2 RPB $M_{1}(MPa) = 1.47 \times 10^{9} f_{1}(\phi)^{2.213} f_{2}(\phi)^{0.413}$ 36 0.76 0.2 RPB $M_{1}(MPa) = 4.80 f_{1}(\phi)^{0.404}$ 36 0.76 0.2 RPB $M_{1}(MPa) = 8.64 (w_{1}/w_{1})^{-1.213}$ 87 0.92 0.7 Thawed RPB $M_{1}(MPa) = 8.64 (w_{1}/w_{1})^{-1.213} f_{1}(\phi)^{0.404}$ 119 0.84 0.3 Thawed RPB $M_{1}(MPa) = 8.129 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{1}(\phi)^{0.404}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{1}(\phi)^{0.402}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{1}(\phi)^{0.402}$ 119 0.89 0.2 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{1}(\phi)^{0.402}$ 180 0.89 0.9 D.9 0.6 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{1}(\phi)^{0.402}$ 188 0.95 0.3 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.3 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.3 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.5 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.6 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.6 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.0 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 188 0.95 0.0 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.402}$ 180 0.95 0.0 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.1.504}$ 199 0.95 0.0 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.1.504}$ 190 0.95 0.0 RPB $M_{1}(MPa) = 3.021 \times 10^{7} f_{2}(\phi)^{1.1.504} f_{2}(\phi)^{0.1.504}$ 190 0.95 0.0 RPB $M_{1}(MPa) = 3.02$		RPB			0.91	0.50
FWD $M_{f}(MPa) = 9.27 \times 10^{4} f(\phi)^{2.09} f(\sigma)^{0.07}$ 222 0.71 0.2 RPB $M_{f}(MPa) = 1.68 \times 10^{4} f(\phi)^{2.19} f_{f}(\sigma)^{0.14}$ 186 0.89 0.1 FWD $M_{f}(MPa) = 1.47 \times 10^{4} f(\phi)^{2.19} f_{f}(\sigma)^{0.14}$ 222 0.86 0.1 Recovered RPB $M_{f}(MPa) = 1.47 \times 10^{4} f(\phi)^{2.19} f_{f}(\sigma)^{0.14}$ 36 0.76 0.2 RPB $M_{f}(MPa) = 6.89 f_{f}(\sigma)^{6.19}$ 36 0.87 0.1 Relamina sand  Frozen RPB $M_{f}(MPa) = 4.80 f_{f}(\sigma)^{6.06}$ 87 0.1 RPB $M_{f}(MPa) = 8.129 \times 10^{4} f(\phi)^{1.19} f_{f}(\sigma)^{0.192}$ 87 0.92 0.7 Thawed RPB $M_{f}(MPa) = 8.129 \times 10^{4} f(\phi)^{1.192} f_{f}(\sigma)^{1.179} f_{f}(\sigma)^{6.06}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 3.021 \times 10^{4} f(\phi)^{1.139} f_{f}(\sigma)^{1.179} f_{f}(\sigma)^{6.42}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 5.69 \times 10^{4} f(\phi)^{1.139} f_{f}(\sigma)^{0.139}$ 38 0.84 0.2 RPB $M_{f}(MPa) = 2.405 \times 10^{4} f(\phi)^{1.139} f_{f}(\sigma)^{0.42}$ 38 0.84 0.2 RPB $M_{f}(MPa) = 8.05 \times 10^{4} f(\phi)^{1.192} f_{f}(\sigma)^{0.42}$ 38 0.84 0.2 RPB $M_{f}(MPa) = 4.689 \times 10^{4} f(\phi)^{1.192} f_{f}(\sigma)^{0.42}$ 88 0.95 0.1 RPB $M_{f}(MPa) = 4.689 \times 10^{4} f_{f}(\sigma)^{0.442} f_{f}(\sigma)^{0.442}$ 88 0.96 0.4 FWD $M_{f}(MPa) = 4.689 \times 10^{4} f_{f}(\sigma)^{0.442} f_{f}(\sigma)^{0.442}$ 88 0.97 0.4 FWD $M_{f}(MPa) = 3.93 \times 10^{4} f_{f}(\sigma)^{0.149} f_{f}(\sigma)^{0.441} f_{f}(\sigma)^{0.441}$ 174 0.71 0.2 RPB $M_{f}(MPa) = 1.269 \times 10^{4} f_{f}(\sigma)^{0.149} f_{f}(\sigma)^{0.19} f_{f}(\sigma)^$	FWD $M_{f}(MPa) = 9.27 \times 10^{4} f(\phi)^{2.09} f(\sigma)^{0.47}$ 222 0.71 0.2 RPB $M_{f}(MPa) = 1.68 \times 10^{4} f(\phi)^{2.19} f(\sigma)^{0.41}$ 186 0.89 0.1 FWD $M_{f}(MPa) = 1.47 \times 10^{4} f(\phi)^{2.19} f(\sigma)^{0.41}$ 222 0.86 0.1 Recovered RPB $M_{f}(MPa) = 1.47 \times 10^{4} f(\psi)^{2.19} f(\sigma)^{0.41}$ 36 0.76 0.2 RPB $M_{f}(MPa) = 1.49 \times 10^{4} f(\phi)^{2.19} f(\sigma)^{0.41}$ 36 0.76 0.2 RPB $M_{f}(MPa) = 4.80 f(\sigma)^{2.09} e^{0.04}$ 36 0.87 0.1 Relamina sand Frozen RPB $M_{f}(MPa) = 8.05 \cdot 10^{4} f(\phi)^{-1.19} f(\sigma)^{-0.04}$ 87 0.92 0.7 Thawed RPB $M_{f}(MPa) = 8.129 \times 10^{4} f(\psi)^{-1.20} f(\psi)^{-1.19} f(\sigma)^{0.40}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 3.021 \times 10^{4} f(\psi)^{-1.20} f(\gamma)^{11.270} f(\sigma)^{0.40}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 5.69 \times 10^{4} f(\phi)^{-1.10} f(\sigma)^{0.217}$ 38 0.88 0.2 RPB $M_{f}(MPa) = 2.405 \times 10^{4} f(\psi)^{-1.20} f(\gamma)^{11.20} f(\sigma)^{0.42}$ 38 0.84 0.2 RPB $M_{f}(MPa) = 3.828 (w_{e}/w_{e})^{1.72}$ 88 0.95 0.1 RPB $M_{f}(MPa) = 4.689 \times 10^{4} f(\psi)^{-1.20} f(\phi)^{0.42}$ 88 0.95 0.1 RPB $M_{f}(MPa) = 4.689 \times 10^{4} f(\psi)^{-1.20} f(\phi)^{0.42}$ 88 0.95 0.1 RPB $M_{f}(MPa) = 4.689 \times 10^{4} f(\psi)^{-1.20} f(\phi)^{0.242}$ 88 0.96 0.4 FWD $M_{f}(MPa) = 3.93 \times 10^{4} f(\psi)^{-1.20} f(\psi)^{-1.2$		FWD	•	73	0.95	0.4
RPB $M_{t}(MPa) = 6.68 \times 10^{t} f(\phi)^{2.234} f_{t}(\phi)^{0.414}$ 186 0.89 0.1: FWD $M_{t}(MPa) = 6.89 f_{t}(\phi)^{0.234} f_{t}(\phi)^{0.415}$ 222 0.86 0.1: Recovered RPB $M_{t}(MPa) = 6.89 f_{t}(\phi)^{0.415}$ 36 0.87 0.1: Relamina sand Frozen RPB $M_{t}(MPa) = 6.89 f_{t}(\phi)^{0.404}$ 36 0.87 0.1: Relamina sand Frozen RPB $M_{t}(MPa) = 6.89 f_{t}(\phi)^{0.404}$ 87 0.92 0.7: Thawed RPB $M_{t}(MPa) = 8.129 \times 10^{t} f_{t}(\phi)^{1.134} f_{t}(\phi)^{1.135} f_{t}(\phi)^{0.405}$ 119 0.84 0.3: Thawed RPB $M_{t}(MPa) = 8.129 \times 10^{t} f_{t}(\phi)^{1.134} f_{t}(\phi)^{1.135} f_{t}(\phi)^{0.405}$ 119 0.89 0.2 Recovered RPB $M_{t}(MPa) = 3.021 \times 10^{t} f_{t}(\phi)^{1.134} f_{t}(\phi)^{1.134} f_{t}(\phi)^{0.405}$ 119 0.89 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{t} f_{t}(\phi)^{1.134} f_{t}(\phi)^{0.405}$ 188 0.84 0.2 RPB $M_{t}(MPa) = 8.05 \times 10^{t} f_{t}(\phi)^{1.134} f_{t}(\phi)^{0.405}$ 188 0.95 0.5 RPB $M_{t}(MPa) = 8.05 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 188 0.95 0.5 RPB $M_{t}(MPa) = 8.05 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 188 0.96 0.4 FWD $M_{t}(MPa) = 8.05 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 189 0.95 0.5 RPB $M_{t}(MPa) = 2.97 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 197 0.4 RPB $M_{t}(MPa) = 2.97 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 197 0.4 RPB $M_{t}(MPa) = 1.269 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 197 0.4 RPB $M_{t}(MPa) = 1.269 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.405} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.2 RPB $M_{t}(MPa) = 3.381 \times 10^{t} f_{t}(\phi)^{0.135} f_{t}(\phi)^{0.405}$ 104 0.6 0.6 0.0 0.5 RPB $M_{t}(MPa) = 3.34.5 (w, w)^{1.135} f_{t}(\phi)^{0.135} f_{t}(\phi)^{0.355}$ 104 0.6 0.6 0.0 0.	RPB $M_{f}(MPa) = 6.58 \times 10^{6} f(\phi)^{2.294a} f_{f}(\phi)^{0.414}$ 186 0.89 0.1 FWD $M_{f}(MPa) = 1.47 \times 10^{6} f(\phi)^{2.13} f_{f}(\phi)^{0.413}$ 222 0.86 0.1 Recovered RPB $M_{f}(MPa) = 6.89 f_{f}(\phi)^{0.413}$ 36 0.76 0.2 RPB $M_{f}(MPa) = 4.80 f_{f}(\phi)^{0.404a}$ 36 0.87 0.1 Realization send Frozen RPB $M_{f}(MPa) = 4.80 f_{f}(\phi)^{0.404a}$ 87 0.92 0.7 Thaved RPB $M_{f}(MPa) = 8.129 \times 10^{6} f_{f}(\phi)^{0.404a}$ 87 0.92 0.7 Thaved RPB $M_{f}(MPa) = 8.129 \times 10^{6} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{0.402}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 3.021 \times 10^{6} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{0.402}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 2.405 \times 10^{6} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{0.402}$ 38 0.88 0.2 RPB $M_{f}(MPa) = 3.809 \times 10^{6} f_{f}(\phi)^{1.137a} f_{f}(\phi)^{0.402}$ 38 0.88 0.2 RPB $M_{f}(MPa) = 4.085 \times 10^{6} f_{f}(\phi)^{0.402}$ 88 0.95 0.1 FWD $M_{f}(MPa) = 4.085 \times 10^{6} f_{f}(\phi)^{0.402}$ 88 0.95 0.1 FWD $M_{f}(MPa) = 4.085 \times 10^{6} f_{f}(\phi)^{0.402}$ 88 0.95 0.1 FWD $M_{f}(MPa) = 4.085 \times 10^{6} f_{f}(\phi)^{0.402} f_{f}(\phi)^{0.402}$ 117 0.71 0.2 RPB $M_{f}(MPa) = 2.97 \times 10^{6} f_{f}(\phi)^{0.404} f_{f}(\phi)^{0.403}$ 117 0.71 0.2 RPB $M_{f}(MPa) = 2.97 \times 10^{6} f_{f}(\phi)^{0.104} f_{f}(\phi)^{0.403}$ 117 0.71 0.2 RPB $M_{f}(MPa) = 3.39 \times 10^{6} f_{f}(\phi)^{6} f_{f}(\phi)^{6} f_{f}(\phi)^{0.403}$ 117 0.71 0.2 FWD $M_{f}(MPa) = 3.39 \times 10^{6} f_{f}(\phi)^{1.136} f_{f}(\phi)^{0.403}$ 117 0.87 0.1 FWD $M_{f}(MPa) = 3.31 \times 10^{6} f_{f}(\phi)^{1.136} f_{f}(\phi)^{0.403}$ 117 0.97 0.09 0.95 0.6 Dessegraded stone FWD $M_{f}(MPa) = 3.57 \times 10^{6} f_{f}(\phi)^{1.136} f_{f}(\phi)^{0.133}$ 106 0.07 0.1 RPB $M_{f}(MPa) = 1.01 \times 10^{6} f_{f}(\phi)^{1.136} f_{f}(\phi)^{0.133}$ 107 0.1 18 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3	Thawed	RPB	$M_{\rm r}({\rm MPa}) = 2.139 \times 10^4 f(\psi)^{-2.7925} f_1(\sigma)^{0.462}$	186	0.76	0.2
FWD $M_t(MPa) = 1.47 \times 10^4 f(\psi)^{-2.75} f_t(\phi)^{0.413}$ 222 0.86 0.1.  Recovered RPB $M_t(MPa) = 6.89 f_t(\phi)^{0.414}$ 36 0.76 0.2.  RPB $M_t(MPa) = 4.80 f_t(\phi)^{0.446}$ 36 0.87 0.11  Ralanian sand  Frozen RPB $M_t(MPa) = 8.09 f_t(\phi)^{0.4046}$ 62 0.90 0.31  RPB $M_t(MPa) = 8.09 f_t(\phi)^{0.4046}$ 87 0.92 0.77  Thawed RPB $M_t(MPa) = 8.129 \times 10^4 f_t(\phi)^{-2.138} f_t(\phi)^{0.415} f_t(\phi)^{0.441}$ 119 0.89 0.2  Recovered RPB $M_t(MPa) = 3.021 \times 10^4 f_t(\phi)^{-2.132} f_t(\phi)^{0.442}$ 119 0.88 0.2  Recovered RPB $M_t(MPa) = 3.021 \times 10^4 f_t(\phi)^{-1.108} f_t(\phi)^{0.442}$ 38 0.88 0.2  RPB $M_t(MPa) = 3.021 \times 10^4 f_t(\phi)^{-1.108} f_t(\phi)^{0.442}$ 38 0.88 0.2  RPB $M_t(MPa) = 3.021 \times 10^4 f_t(\phi)^{-1.108} f_t(\phi)^{0.442}$ 38 0.95 0.2  RPB $M_t(MPa) = 3.021 \times 10^4 f_t(\phi)^{-1.108} f_t(\phi)^{0.442}$ 88 0.97 0.4  FWD $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.109} f_t(\phi)^{0.442}$ 88 0.97 0.4  FWD $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.109} f_t(\phi)^{0.442}$ 88 0.97 0.4  FWD $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.442}$ 88 0.97 0.4  FWD $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.442} f_t(\phi)^{-1.19}$ 88 0.97 0.4  Thawed RPB $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.45} f_t(\phi)^{-1.19}$ 164 0.67 0.2  RPB $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.45} f_t(\phi)^{0.451}$ 174 0.87 0.1  FWD $M_t(MPa) = 3.05 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.109} f_t(\phi)^{-0.19}$ 164 0.67 0.2  FWD $M_t(MPa) = 3.09 \times 10^4 f_t(\phi)^{-1.19} f_t(\phi)^{0.109} f_t(\phi)^{-0.19} f_t(\phi)^{0.109} $	FWD $M_t(MPa) = 1.47 \times 10^4 f(\psi)^{-2.75} f_t(\phi)^{0.413}$ 222 0.86 0.1 Recovered RPB $M_t(MPa) = 6.89 f_t(\phi)^{0.446}$ 36 0.76 0.2 RPB $M_t(MPa) = 4.80 f_t(\phi)^{0.446}$ 36 0.87 0.1 Ralanian sand  Frozen RPB $M_t(MPa) = 4.80 f_t(\phi)^{0.446}$ 62 0.90 0.3 $+ (0.04416) w^3 [r_{out}/\sigma_0)^{-0.342}$ 87 0.92 0.7 RPB $M_t(MPa) = 8.6.4 (w_t/w_t)^{-1.13}$ 87 0.92 0.7 Thawed RPB $M_t(MPa) = 8.129 \times 10^4 f(\psi)^{-1.128} f_t(\phi)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.138} f_t(\phi)^{0.442}$ 119 0.80 0.2 RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 38 0.88 0.2 RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 38 0.88 0.2 RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 89 0.90 0.3 RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 38 0.88 0.2 RPB $M_t(MPa) = 3.021 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 38 0.89 0.2 RPB $M_t(MPa) = 3.05 \times 10^4 f(\psi)^{-1.148} f_t(\phi)^{0.442}$ 89 0.99 0.92 0.6 RPB $M_t(MPa) = 4.05 \times 10^4 f(\psi)^{-1.19} f_t(\phi)^{0.442}$ 88 0.97 0.4 FWD $M_t(MPa) = 8.05 \times 10^4 f(\psi)^{-1.19} f_t(\phi)^{0.442}$ 88 0.97 0.4 FWD $M_t(MPa) = 3.05 \times 10^4 f(\psi)^{-1.09} f(\phi)^{-0.35} (w_t/w_t)^{-1.19}$ 88 0.97 0.4 FWD $M_t(MPa) = 3.05 \times 10^4 f(\psi)^{-1.09} f(\phi)^{-0.35} f(\psi)^{-1.19} f_t(\phi)^{-0.45}$ 174 0.87 0.1 FWD $M_t(MPa) = 3.05 \times 10^4 f(\psi)^{-1.09} f(\psi)^{-1.09} f(\phi)^{-0.45}$ 174 0.87 0.1 FWD $M_t(MPa) = 3.09 \times 10^4 f(\psi)^{-1.19} f(\psi)^{-1.19} f_t(\phi)^{0.451}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.09 \times 10^4 f(\psi)^{-1.19} f(\psi)^{-1.19} f_t(\phi)^{0.351}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.09 \times 10^4 f(\psi)^{-1.19} f(\psi)^{-1.19} f_t(\phi)^{0.351}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.18 \times 10^4 f(\psi)^{-1.19} f_t(\phi)^{0.19} f(\phi)^{-1.19} f_t(\phi)^{0.351}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.18 \times 10^4 f(\psi)^{-1.19} f_t(\phi)^{0.19} f(\phi)^{-1.19} f_t(\phi)^{0.351}$ 174 0.87 0.1 FWD $M_t(MPa) = 3.18 \times 10^4 f(\psi)^{-1.19} f_t(\phi)^{0.19} f(\phi)^{0.19} f(\phi)^{0.1$		FWD	$M_{\rm r}({\rm MPa}) = 9.27 \times 10^3 f(\psi)^{-2.60} f_1(\sigma)^{0.477}$	222	0.71	0.2
Recovered RPB $M_{t}(MPa) = 6.89 f_{t}(op^{0.418})$ 36 0.76 0.2 RPB $M_{t}(MPa) = 4.80 f_{t}(op^{0.406})$ 36 0.87 0.11 Relatation stand  Frozen RPB $M_{t}(MPa) = 4.80 f_{t}(op^{0.406})$ 62 0.90 0.31 RPB $M_{t}(MPa) = 8.129 \times 10^{4} f_{t}(o^{0.4016})^{11/10} f_{t}(o^{0.402})^{-0.302}$ 87 0.92 0.7 Thawed RPB $M_{t}(MPa) = 8.129 \times 10^{4} f_{t}(v)^{-1.329} f_{t}(o^{0.402})$ 119 0.84 0.3 RPB $M_{t}(MPa) = 8.129 \times 10^{4} f_{t}(v)^{-1.329} f_{t}(o^{0.402})$ 119 0.89 0.2 Recovered RPB $M_{t}(MPa) = 3.021 \times 10^{4} f_{t}(v)^{-1.329} f_{t}(o^{0.402})$ 119 0.89 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{4} f_{t}(v)^{-1.329} f_{t}(o^{0.402})$ 38 0.84 0.2 RPB $M_{t}(MPa) = 3.69 \times 10^{4} f_{t}(v)^{-1.209} f_{t}(o^{0.402})$ 38 0.84 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(v)^{-1.209} f_{t}(o^{0.402})$ 88 0.95 0.5 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(v)^{-1.209} f_{t}(o^{0.402})$ 88 0.95 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(o^{0.402})$ 88 0.95 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 4.085 \times 10^{4} f_{t}(o^{0.402}) f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 2.97 \times 10^{4} f_{t}(v)^{1.009} f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.93 \times 10^{4} f_{t}(v)^{1.009} f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.93 \times 10^{4} f_{t}(v)^{1.009} f_{t}(o^{0.402}) f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.93 \times 10^{4} f_{t}(v)^{1.009} f_{t}(v)^{1.009} f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.93 \times 10^{4} f_{t}(v)^{1.009} f_{t}(v)^{1.009} f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.31 \times 10^{4} f_{t}(v)^{1.109} f_{t}(v)^{1.109} f_{t}(o^{0.402})$ 174 0.71 0.2 RPB $M_{t}(MPa) = 3.51 \times 10^{4} f_{t}(v)^{1.109} f_{t}(v)^{1.109} f_{t}(o^{0.402})$ 175 164 0.67 0.2 RPB $M_{t}(MPa) = 3.57 \times 10^{4} f_{t}(v)^{1.109} f_{t}(o^{0.109} f_{t}(o^{0.109} f_{t}(o^{0.109} f_{t}(o^{0.109} f_{t}(o^{0.109} f_{t}(o^{0.109} f_{t}(o^{0.$	Recovered RPB $M_t(MPa) = 6.89 f_t(op^{0.41})$ 36 0.76 0.2 RPB $M_t(MPa) = 4.80 f_t(op^{0.41})$ 36 0.87 0.1 Relatation sand  Frozen RPB $M_t(MPa) = 4.80 f_t(op^{0.404})$ 62 0.90 0.3 RPB $M_t(MPa) = 8.129 \times 10^4 f_t(o_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.32} f_t(op^{0.400})$ 17 0.8378)w 62 0.90 0.3 RPB $M_t(MPa) = 8.129 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.32} f_t(op^{0.400})$ 19 0.84 0.3 RPB $M_t(MPa) = 8.129 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.400})$ 119 0.84 0.3 RPB $M_t(MPa) = 5.69 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.400})$ 119 0.89 0.2 0.7 RPB $M_t(MPa) = 5.69 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 119 0.89 0.2 0.6 RPB $M_t(MPa) = 5.69 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 38 0.84 0.2 RPB $M_t(MPa) = 5.69 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 38 0.84 0.2 RPB $M_t(MPa) = 5.69 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 38 0.95 0.1 RPB $M_t(MPa) = 4.085 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 38 0.95 0.1 RPB $M_t(MPa) = 4.689 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 18 0.90 0.0 RPB $M_t(MPa) = 4.698 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 17 0.2 RPB $M_t(MPa) = 4.598 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 17 0.2 RPB $M_t(MPa) = 3.93 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 17 0.0 0.7 RPB $M_t(MPa) = 3.93 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 17 0.0 RPB $M_t(MPa) = 3.93 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 17 0.0 RPB $M_t(MPa) = 3.31 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 10 0.1 Prozen RPB $M_t(MPa) = 3.51 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.402})$ 10 0.1 RPB $M_t(MPa) = 3.57 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(op^{0.102})$ 118 0.63 0.2 RPB $M_t(MPa) = 7.47 \times 10^4 f_t(v_{exc}^{1/2} \sigma_{op}^{1/2})^{-3.127} f_t(v_{exc}^{1/2} \sigma_{op}^$		RPB	•••	186	0.89	0.1
Realization   RPB   $M_t(MPa) = 4.80 f_t(\sigma)^{0.0046}  $   36   0.87   0.11	RPB   $M_t(MPa) = 4.80 f_t(\sigma)^{0.004}  $   36   0.87   0.1     Realmains small   Frozen   RPB   $M_t(GPa) = \exp[13.74 - (0.820)T - (0.0538)T^{-}(0.8378)w $   62   0.90   0.3     $+ (0.04416)w^{-} (\tau_{cot}/\sigma_c)^{-0.382}  $   87   0.92   0.7     Thawed   RPB   $M_t(MPa) = 8.129 \times 10^{9} f_t(\psi)^{-1.378} f_t(\sigma)^{0.402}  $   119   0.84   0.3     RPB   $M_t(MPa) = 3.021 \times 10^{9} f_t(\psi)^{-1.386} f_t(\gamma)^{11.578} f_t(\sigma)^{0.402}  $   119   0.89   0.2     RPB   $M_t(MPa) = 3.021 \times 10^{9} f_t(\psi)^{-1.105} f_t(\sigma)^{0.402}  $   119   0.89   0.2     RPB   $M_t(MPa) = 3.09 \times 10^{9} f_t(\psi)^{-1.105} f_t(\sigma)^{0.402}  $   38   0.88   0.2     RPB   $M_t(MPa) = 3.828(w_d/w_t)^{-1.79}  $   38   0.89   0.2     RPB   $M_t(MPa) = 3.828(w_d/w_t)^{-1.29}  $   38   0.95   0.3     FWD   $M_t(MPa) = 3.803 \times 10^{9} f_t(\psi)^{-1.09} f_t(\sigma)^{0.402}  $   88   0.97   0.4     FWD   $M_t(MPa) = 3.803 \times 10^{19} f_t(\sigma)^{0.405} f_t(w_t/w_t)^{-1.97}  $   88   0.97   0.4     FWD   $M_t(MPa) = 3.803 \times 10^{19} f_t(\sigma)^{0.405} f_t(w_t/w_t)^{-1.97}  $   88   0.97   0.4     FWD   $M_t(MPa) = 3.93 \times 10^{19} f_t(\phi)^{1.09} f_t(\phi)^{1$				222	0.86	0.1
Fixed RPB $M_{r}(GPa) = \exp[13.74 - (0.820)T - (0.0538)T^{-}(0.8378)w + (0.04416)w^{-1}(T_{coc}/\sigma_{o})^{-0.312}$ RPB $M_{r}(MPa) = 86.4(w_{r}/w_{r})^{-1.32}$ RPB $M_{r}(MPa) = 86.4(w_{r}/w_{r})^{-1.32}$ RPB $M_{r}(MPa) = 8.129 \times 10^{r} f(\psi)^{-1.328} f(\gamma)^{11.578} f_{r}(\sigma)^{0.400}$ 119 0.84 0.3  RPB $M_{r}(MPa) = 3.129 \times 10^{r} f(\psi)^{-3.318} f(\gamma)^{11.578} f_{r}(\sigma)^{0.402}$ 119 0.89 0.2  Recovered RPB $M_{r}(MPa) = 5.69 \times 10^{r} f(\psi)^{-3.318} f_{r}(\sigma)^{0.402}$ 119 0.89 0.2  Recovered RPB $M_{r}(MPa) = 5.69 \times 10^{r} f(\psi)^{-3.318} f_{r}(\sigma)^{0.402}$ 138 0.88 0.2  RPB $M_{r}(MPa) = 2.405 \times 10^{r} f(\psi)^{-3.318} f_{r}(\sigma)^{0.402}$ 138 0.88 0.2  Hart Brothers sand  Frozen FWD $M_{r}(MPa) = 4.085 \times 10^{r} f(\psi)^{-1.79} f_{r}(\sigma)^{0.402}$ 88 0.95 0.3  FWD $M_{r}(MPa) = 4.085 \times 10^{r} f(\psi)^{-1.79} f_{r}(\sigma)^{0.402}$ 88 0.97 0.4  FWD $M_{r}(MPa) = 4.085 \times 10^{r} f(\pi)^{-1.79} f_{r}(\sigma)^{0.402}$ 89 0.92 0.6  FWD $M_{r}(MPa) = 4.085 \times 10^{r} f(\pi)^{-1.79} f_{r}(\sigma)^{0.402} f_{r}(\pi)^{-1.79}$ 88 0.97 0.4  FWD $M_{r}(MPa) = 2.97 \times 10^{r} f(\psi)^{-1.09} f_{r}(\eta)^{7.02} f_{r}(\sigma)^{6.402}$ 174 0.71 0.2  RPB $M_{r}(MPa) = 2.97 \times 10^{r} f(\psi)^{-1.09} f_{r}(\eta)^{7.02} f_{r}(\sigma)^{6.402}$ 174 0.71 0.2  RPB $M_{r}(MPa) = 2.99 \times 10^{r} f(\psi)^{-1.29} f_{r}(\eta)^{7.01} f_{r}(\sigma)^{6.402}$ FWD $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-1.29} f_{r}(\eta)^{7.12} f_{r}(\sigma)^{6.402}$ 174 0.71 0.2  RPB $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-1.29} f_{r}(\eta)^{7.12} f_{r}(\sigma)^{6.452}$ 174 0.71 0.2  FWD $M_{r}(MPa) = 3.81 \times 10^{r} f(\psi)^{-1.29} f_{r}(\eta)^{7.12} f_{r}(\sigma)^{6.452}$ 175 164 0.67 0.2  FWD $M_{r}(MPa) = 3.3.45 (w_{r}/w_{r})^{-1.29}$ 176 0.90 0.5  Thawed FWD $M_{r}(MPa) = 3.57 \times 10^{r} f(\psi)^{-1.29} f_{r}(\eta)^{6.19} f_{r}(\sigma)^{6.452}$ 176 0.90 0.5  Thawed RPB $M_{r}(MPa) = 1.147 \times 10^{r} f(\psi)^{-1.29} f_{r}(\sigma)^{6.452}$ 177 0.90 0.90 0.5  Shbety till  FYD $M_{r}(MPa) = 1.147 \times 10^{r} f(\psi)^{-1.29} f_{r}(\sigma)^{6.152}$ 178 0.91 0.91 0.92 0.92 0.6  RPB $M_{r}(MPa) = 1.56 \times 10^{r} f_{r}(\psi)^{-1.29} f_{r}(\sigma)^{6.19} f_{r}(\sigma)^{6.19} f_{r}(\sigma)^{6.19} f_{r}(\sigma)^{6.19} f_{r}(\sigma)^{$	Fixes and Frozen RPB $M_{r}(GPa) = \exp[13.74 - (0.820)T - (0.0538)T^{2} - (0.8378)w + (0.04416)w^{2} _{Tocc}/\sigma_{0})^{-0.312}$ RPB $M_{r}(MPa) = 86.4(w_{r}/w_{r})^{-1.32}$ RPB $M_{r}(MPa) = 86.4(w_{r}/w_{r})^{-1.32}$ RPB $M_{r}(MPa) = 8.129 \times 10^{r} f(\psi)^{-1.328} f(\tau)^{-11.578} f_{r}(\sigma)^{0.400}$ RPB $M_{r}(MPa) = 3.021 \times 10^{r} f(\psi)^{-1.328} f(\tau)^{-11.578} f_{r}(\sigma)^{0.400}$ RPB $M_{r}(MPa) = 3.021 \times 10^{r} f(\psi)^{-1.328} f(\tau)^{-11.578} f_{r}(\sigma)^{0.442}$ RPB $M_{r}(MPa) = 5.021 \times 10^{r} f(\psi)^{-1.318} f_{r}(\sigma)^{0.327}$ RPB $M_{r}(MPa) = 2.405 \times 10^{r} f(\psi)^{-1.318} f_{r}(\sigma)^{0.442}$ RPB $M_{r}(MPa) = 2.405 \times 10^{r} f(\psi)^{-1.318} f_{r}(\sigma)^{0.442}$ RPB $M_{r}(MPa) = 4.085 \times 10^{r} f(\psi)^{-1.319} f_{r}(\sigma)^{0.442}$ RPB $M_{r}(MPa) = 4.085 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.442}$ RPB $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.432} f_{r}(\sigma)^{0.432}$ RPB $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.432} f_{r}(\sigma)^{0.432}$ RPB $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.432}$ RPB $M_{r}(MPa) = 3.81 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.432}$ RPB $M_{r}(MPa) = 3.81 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.322}$ RPB $M_{r}(MPa) = 3.3.45 (w_{r}/w_{r})^{-1.32} f_{r}(\sigma)^{0.322}$ RPB $M_{r}(MPa) = 1.147 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.322}$ RPB $M_{r}(MPa) = 1.147 \times 10^{r} f(\psi)^{-1.329} f_{r}(\sigma)^{0.322}$ RPB $M_{r}(MPa) = 1.147 \times 10^{r} f(\psi)^$	Recovered		•		0.76	0.24
Frozen RPB $M_{\rm f}({\rm GPa}) = \exp[13.74-(0.820)T-(0.0538)T^{2}-(0.8378)w + (0.04416)w^{2}(c_{\rm ex}/\sigma_{0})^{-0.312}$ RPB $M_{\rm f}({\rm MPa}) = 86.4(w_{\rm e}/w_{\rm f})^{-1.32}$ 87 0.92 0.7  Thawed RPB $M_{\rm f}({\rm MPa}) = 8.129 \times 10^{6} f(\psi_{\rm f})^{-3.224} f(\gamma_{\rm f})^{11.578} f_{1}(\sigma_{\rm f})^{0.490}$ 119 0.84 0.3  RPB $M_{\rm f}({\rm MPa}) = 3.021 \times 10^{6} f(\psi_{\rm f})^{-3.224} f(\gamma_{\rm f})^{11.578} f_{1}(\sigma_{\rm f})^{0.492}$ 119 0.89 0.2  Recovered RPB $M_{\rm f}({\rm MPa}) = 5.69 \times 10^{6} f(\psi_{\rm f})^{-3.234} f(\gamma_{\rm f})^{11.584} f_{1}(\sigma_{\rm f})^{0.492}$ 180 0.88 0.28  RPB $M_{\rm f}({\rm MPa}) = 2.405 \times 10^{6} f(\psi_{\rm f})^{-3.198} f_{1}(\sigma_{\rm f})^{0.492}$ 180 0.88 0.24  Hart Brothers sand  Frozen FWD $M_{\rm f}({\rm MPa}) = 3.828(w_{\rm e}/w_{\rm f})^{-1.39} f_{1}(\sigma_{\rm f})^{0.492}$ 180 0.95 0.2  RPB $M_{\rm f}({\rm MPa}) = 4.085 \times 10^{10} f(\psi_{\rm f})^{-3.084} (w_{\rm e}/w_{\rm f})^{-1.97}$ 180 0.95 0.2  RPB $M_{\rm f}({\rm MPa}) = 4.085 \times 10^{10} f(\psi_{\rm f})^{-3.084} (w_{\rm e}/w_{\rm f})^{-1.97}$ 181 0.95 0.2  RPB $M_{\rm f}({\rm MPa}) = 4.689 \times 10^{10} f(\phi_{\rm f})^{-3.084} (w_{\rm e}/w_{\rm f})^{-1.97}$ 182 0.95 0.2  RPB $M_{\rm f}({\rm MPa}) = 4.689 \times 10^{10} f(\phi_{\rm f})^{-3.084} (w_{\rm e}/w_{\rm f})^{-1.97}$ 183 0.96 0.2  RPB $M_{\rm f}({\rm MPa}) = 1.2.69 \times 10^{10} f(\psi_{\rm f})^{-3.09} f(\gamma_{\rm f})^{-3.09} f(\sigma_{\rm f})^{-3.09}$ 174 0.71 0.2  RPB $M_{\rm f}({\rm MPa}) = 1.2.69 \times 10^{10} f(\psi_{\rm f})^{-3.09} f(\gamma_{\rm f})^{-3.09} f(\sigma_{\rm f})^{-3.09}$ 174 0.71 0.2  RPB $M_{\rm f}({\rm MPa}) = 3.93 \times 10^{10} f(\psi_{\rm f})^{-3.09} f(\gamma_{\rm f})^{-3.09} f(\sigma_{\rm f})^{-3.09}$ 174 0.67 0.2  FWD $M_{\rm f}({\rm MPa}) = 3.3.45(w_{\rm e}/w_{\rm f})^{-3.09}$ 175 0.90 0.55 0.0  RPB $M_{\rm f}({\rm MPa}) = 3.57 \times 10^{10} f(\psi_{\rm f})^{-3.09} f(\sigma_{\rm f})^{-3.09}$ 174 0.67 0.2  RPB $M_{\rm f}({\rm MPa}) = 3.57 \times 10^{10} f(\psi_{\rm f})^{-3.09} f(\sigma_{\rm f})^{-3.09}$ 175 0.1  RPB $M_{\rm f}({\rm MPa}) = 1.10 \times 10^{10} (w_{\rm e}/w_{\rm f})^{-3.19}$ 176 0.90 0.95 0.6  RPB $M_{\rm f}({\rm MPa}) = 1.10 \times 10^{10} (w_{\rm e}/w_{\rm f})^{-3.09}$ 177 0.1  RPB $M_{\rm f}({\rm MPa}) = 1.10 \times 10^{10} (w_{\rm e}/w_{\rm f})^{-3.09}$ 179 0.10 0.90 0.95 0.95 0.95 0.95	Frozen RPB $M_{r}(GPa) = \exp[13.74-(0.820)T-(0.0538)T^{-}(0.8378)w$ 62 0.90 0.3 RPB $M_{r}(GPa) = \exp[13.74-(0.820)T-(0.0538)T^{-}(0.8378)w$ 62 0.90 0.3 RPB $M_{r}(MPa) = 8.129 \times 10^{r} f(w)^{-1.324} f(\gamma)^{11.578} f_{1}(\sigma)^{0.490}$ 119 0.84 0.3 RPB $M_{r}(MPa) = 8.129 \times 10^{r} f(\psi)^{-3.124} f(\gamma)^{11.578} f_{1}(\sigma)^{0.490}$ 119 0.89 0.2 Recovered RPB $M_{r}(MPa) = 5.69 \times 10^{r} f(\psi)^{-3.124} f(\gamma)^{11.544} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2 RPB $M_{r}(MPa) = 5.69 \times 10^{r} f(\psi)^{-3.128} f_{1}(\sigma)^{0.442}$ 38 0.88 0.84 0.2 RPB $M_{r}(MPa) = 2.405 \times 10^{r} f(\psi)^{-3.128} f_{1}(\sigma)^{0.442}$ 38 0.84 0.2 RPB $M_{r}(MPa) = 4.685 \times 10^{r} f(\psi)^{-3.128} f_{1}(\sigma)^{0.442}$ 88 0.95 0.3 RPB $M_{r}(MPa) = 4.685 \times 10^{r} f(\psi)^{-3.128} f_{1}(\sigma)^{0.442}$ 88 0.95 0.4 FWD $M_{r}(MPa) = 4.689 \times 10^{r} f(\sigma)^{0.442} f_{1}(\sigma)^{0.442}$ 88 0.96 0.4 FWD $M_{r}(MPa) = 4.689 \times 10^{r} f(\phi)^{0.444} (w_{w})^{r-1.97}$ 88 0.97 0.4 FWD $M_{r}(MPa) = 4.689 \times 10^{r} f(\phi)^{0.444} (w_{w})^{r-1.97}$ 88 0.96 0.5 RPB $M_{r}(MPa) = 1.269 \times 10^{r} f(\psi)^{-3.09} f(\gamma)^{7.09} f_{1}(\sigma)^{0.43}$ 174 0.71 0.2 RPB $M_{r}(MPa) = 3.93 \times 10^{r} f(\psi)^{-3.09} f(\gamma)^{7.09} f_{1}(\sigma)^{0.437}$ 164 0.67 0.2 FWD $M_{r}(MPa) = 3.345 (w_{w}/w_{w})^{-1.97} f_{1}(\sigma)^{0.437}$ 164 0.67 0.2 FWD $M_{r}(MPa) = 33.45 (w_{w}/w_{w})^{-1.97} f_{1}(\sigma)^{0.437}$ 164 0.67 0.2 FWD $M_{r}(MPa) = 33.45 (w_{w}/w_{w})^{-1.97} f_{1}(\sigma)^{0.244}$ 128 0.71 0.1 FWD $M_{r}(MPa) = 33.45 (w_{w}/w_{w})^{-1.97} f_{1}(\sigma)^{0.244}$ 128 0.71 0.1 FWD $M_{r}(MPa) = 31.77 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.312}$ 164 0.67 0.2 FWD $M_{r}(MPa) = 3.57 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.244}$ 128 0.71 0.1 FWD $M_{r}(MPa) = 1.10 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.312}$ 164 0.65 0.2 RPB $M_{r}(MPa) = 1.10 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.132}$ 118 0.63 0.3 FWD $M_{r}(MPa) = 1.10 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.132}$ 118 0.63 0.3 RPB $M_{r}(MPa) = 1.10 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.132}$ 118 0.63 0.3 RPB $M_{r}(MPa) = 1.10 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^{0.132}$ 118 0.63 0.3 RPB $M_{r}(MPa) = 1.29 \times 10^{r} f(\psi)^{-3.09} f_{1}(\sigma)^$		RPB	$M_{\rm r}({\rm MPa}) = 4.80 f_2(\sigma)^{0.4046}$	36	0.87	0.18
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$						
Thawed RPB $M_{1}(MPa) = 86.4(w_{w}/w_{1})^{-1.32}$ 87 0.92 0.7  Thawed RPB $M_{1}(MPa) = 8.129 \times 10^{17} f(\psi)^{-3.324} f(\gamma)^{11.578} f_{1}(\sigma)^{0.400}$ 119 0.84 0.3  RPB $M_{1}(MPa) = 3.021 \times 10^{17} f(\psi)^{-3.324} f(\gamma)^{11.434} f_{1}(\sigma)^{0.442}$ 119 0.89 0.2.  Recovered RPB $M_{1}(MPa) = 5.69 \times 10^{4} f(\psi)^{-3.118} f_{1}(\sigma)^{0.442}$ 38 0.88 0.2  RPB $M_{1}(MPa) = 2.405 \times 10^{4} f(\psi)^{-2.918} f_{1}(\sigma)^{0.442}$ 38 0.89 0.2  Hart Brothers sand  Frozen FWD $M_{1}(MPa) = 38.28(w_{w}/w_{1})^{-1.72}$ 88 0.95 0.5  RPB $M_{1}(MPa) = 4.085 \times 10^{1} (w_{w}/w_{1})^{-1.99}$ 99 0.92 0.6  FWD $M_{1}(MPa) = 8.05 \times 10^{1} f(\sigma)^{0.442} (w_{w}/w_{1})^{-1.97}$ 88 0.97 0.4  FWD $M_{1}(MPa) = 2.97 \times 10^{1} f(\sigma)^{0.444} (w_{w}/w_{1})^{-1.97}$ 88 0.95 0.4  Thawed RPB $M_{1}(MPa) = 2.97 \times 10^{1} f(\sigma)^{0.444} (w_{w}/w_{1})^{-1.98}$ 88 0.95 0.4  RPB $M_{1}(MPa) = 2.97 \times 10^{1} f(\sigma)^{0.444} (w_{w}/w_{1})^{-1.99}$ 174 0.71 0.2  RPB $M_{1}(MPa) = 3.93 \times 10^{1} f(\psi)^{-2.01} f(\gamma)^{0.01} f_{1}(\sigma)^{0.451}$ 174 0.77 0.2  FWD $M_{1}(MPa) = 3.93 \times 10^{1} f(\psi)^{-2.01} f(\gamma)^{0.01} f_{1}(\sigma)^{0.451}$ 164 0.67 0.2  Hyannis sand  Frozen RPB $M_{1}(MPa) = 3.81 \times 10^{1} f(\psi)^{-2.11} f(\gamma)^{0.01} f_{1}(\sigma)^{0.351}$ 164 0.67 0.2  RPB $M_{1}(MPa) = 3.57 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  Pause-graded stone  Frozen RPB $M_{1}(MPa) = 3.57 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  Pause-graded stone  Frozen RPB $M_{1}(MPa) = 3.57 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  Thawed RPB $M_{1}(MPa) = 7.147 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  Pause-graded stone  Frozen RPB $M_{1}(MPa) = 3.57 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  Frozen RPB $M_{1}(MPa) = 3.57 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 128 0.71 0.1  RPB $M_{1}(MPa) = 7.147 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.344}$ 138 0.63 0.2  RPB $M_{1}(MPa) = 7.17 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.154}$ 64 0.65 0.2  RPB $M_{1}(MPa) = 7.47 \times 10^{1} f(\psi)^{-1.712} f_{1}(\sigma)^{0.172}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus	Thawed RPB $M_t(MPa) = 36.4(w_u/w_t)^{-1.32}$ 87 0.92 0.7  Thawed RPB $M_t(MPa) = 3.129 \times 10^{r} f(\psi)^{-3.334} f(\gamma)^{11.578} f_t(a)^{0.490}$ 119 0.84 0.3  RPB $M_t(MPa) = 3.021 \times 10^{r} f(\psi)^{-3.345} f(\gamma)^{11.634} f_t(a)^{0.442}$ 119 0.89 0.2  Recovered RPB $M_t(MPa) = 2.021 \times 10^{r} f(\psi)^{-3.118} f_t(a)^{0.442}$ 38 0.88 0.2  RPB $M_t(MPa) = 2.405 \times 10^{r} f(\psi)^{-2.918} f_t(a)^{0.442}$ 38 0.84 0.2  Hart Brothers sand  Frozen FWD $M_t(MPa) = 38.28(w_u/w_t)^{-1.722}$ 88 0.95 0.3  RPB $M_t(MPa) = 38.28(w_u/w_t)^{-1.722}$ 88 0.95 0.5  FWD $M_t(MPa) = 6.05 \times 10^{r} f(\psi)^{-2.918} f_t(a)^{0.452}$ 99 0.92 0.6  FWD $M_t(MPa) = 8.05 \times 10^{r} f(\psi)^{-2.918} f_t(a)^{0.452}$ 174 0.71 0.2  RPB $M_t(MPa) = 2.97 \times 10^{r} f(\psi)^{-3.05} f_t(\gamma)^{0.955} f_t(a)^{0.452}$ 174 0.71 0.2  RPB $M_t(MPa) = 2.97 \times 10^{r} f(\psi)^{-2.09} f_t(\gamma)^{5.09} f_t(a)^{0.452}$ 174 0.71 0.2  RPB $M_t(MPa) = 3.93 \times 10^{r} f(\psi)^{-2.497} f_t(\gamma)^{5.09} f_t(a)^{0.452}$ 164 0.67 0.2  FWD $M_t(MPa) = 3.81 \times 10^{r} f(\psi)^{-2.497} f_t(\gamma)^{5.197} f_t(a)^{0.452}$ 164 0.67 0.2  Hyannis sand  Frozen RPB $M_t(MPa) = 3.81 \times 10^{r} f(\psi)^{-2.197} f_t(\gamma)^{5.197} f_t(a)^{0.257}$ 164 0.67 0.2  RPB $M_t(MPa) = 3.51 \times 10^{r} f(\psi)^{-2.197} f_t(\gamma)^{5.197} f_t(a)^{0.452}$ 169 0.95 0.6  Thawed FWD $M_t(MPa) = 3.51 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.354}$ 128 0.71 0.1  Pense-graded stone  Frozen RPB $M_t(MPa) = 3.57 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 128 0.71 0.1  FWD $M_t(MPa) = 3.57 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 18 0.63 0.2  RPB $M_t(MPa) = 7.147 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 18 0.63 0.2  RPB $M_t(MPa) = 7.147 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 18 0.54 0.5  NOTES:  RPB $M_t(MPa) = 7.47 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 18 0.54 0.5  RPB $M_t(MPa) = 7.47 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.154}$ 18 0.54 0.5  NOTES:  RPB $M_t(MPa) = 7.47 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.1725}$ 18 0.6 0.5  RPB $M_t(MPa) = 7.47 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.1725}$ 18 0.7 0.1  RPB $M_t(MPa) = 7.47 \times 10^{r} f(\psi)^{-1.792} f_t(a)^{0.1725}$ 18 0.7 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9	Frozen	RPB		62	0.90	0.3
Thawed RPB $M_1(MPa) = 8.129 \times 10^{4} f(\psi)^{1.378} f(\gamma)^{11.378} f(\alpha)^{0.480}$ 119 0.84 0.3 RPB $M_1(MPa) = 3.021 \times 10^{4} f(\psi)^{1.138} f(\alpha)^{0.480} f(\alpha)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_1(MPa) = 5.69 \times 10^{4} f(\psi)^{-2.118} f(\alpha)^{0.337}$ 38 0.88 0.20 RPB $M_1(MPa) = 2.405 \times 10^{4} f(\psi)^{-2.118} f(\alpha)^{0.337}$ 38 0.88 0.20 RPB $M_1(MPa) = 2.405 \times 10^{4} f(\psi)^{-2.118} f(\alpha)^{0.442}$ 38 0.95 0.5 RPB $M_1(MPa) = 38.28(w_{\alpha}/w_{\alpha})^{-1.722}$ 88 0.95 0.5 FWD $M_1(MPa) = 38.05 \times 10^{4} f(\psi)^{-2.118} f(\alpha)^{0.385} (w_{\alpha}/w_{\alpha})^{-1.37}$ 88 0.95 0.5 FWD $M_1(MPa) = 8.05 \times 10^{-4} f(\gamma_{\alpha})^{-1.64} f(\alpha)^{0.385} (w_{\alpha}/w_{\alpha})^{-1.37}$ 88 0.97 0.4 FWD $M_1(MPa) = 8.05 \times 10^{-4} f(\gamma_{\alpha})^{-1.64} f(\alpha)^{0.385} (w_{\alpha}/w_{\alpha})^{-1.37}$ 88 0.96 0.4 Thawed RPB $M_1(MPa) = 2.97 \times 10^{4} f(\psi)^{-2.083} f(\gamma)^{3.986} f(\alpha)^{0.433}$ 174 0.71 0.2 RPB $M_1(MPa) = 1.269 \times 10^{4} f(\psi)^{-2.67} f(\gamma)^{3.86} f(\alpha)^{0.453}$ 174 0.87 0.1 FWD $M_1(MPa) = 3.93 \times 10^{4} f(\psi)^{-2.67} f(\gamma)^{3.18} f(\alpha)^{0.357}$ 164 0.67 0.2 FWD $M_1(MPa) = 3.81 \times 10^{4} f(\psi)^{-2.817} f(\gamma)^{3.18} f(\alpha)^{0.375}$ 164 0.67 0.2 FWD $M_1(MPa) = 3.81 \times 10^{4} f(\psi)^{-2.117} f(\gamma)^{7.43} f(\alpha)^{0.375}$ 164 0.67 0.2 FWD $M_1(MPa) = 3.57 \times 10^{4} f(\psi)^{-2.117} f(\gamma)^{7.43} f(\alpha)^{0.375}$ 164 0.67 0.2 FWD $M_1(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.712} f(\alpha)^{0.383}$ 174 0.1 0.1 FWD $M_1(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.712} f(\alpha)^{0.385}$ 174 0.1 0.1 FWD $M_1(MPa) = 7.17 \times 10^{4} f(\psi)^{-1.712} f(\alpha)^{0.385}$ 174 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1	Thawed RPB $M_1(MPa) = 8.129 \times 10^n f(\psi)^{-3.334} f(\gamma)^{11.378} f_1(\sigma)^{0.490}$ 119 0.84 0.3 RPB $M_1(MPa) = 3.021 \times 10^n f(\psi)^{-1.265} f_1(\gamma)^{11.534} f_1(\sigma)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_1(MPa) = 5.69 \times 10^n f(\psi)^{-2.165} f_1(\sigma)^{0.537}$ 38 0.88 0.2 RPB $M_1(MPa) = 2.405 \times 10^n f(\psi)^{-2.118} f_1(\sigma)^{0.537}$ 38 0.88 0.2 RPB $M_1(MPa) = 2.405 \times 10^n f(\psi)^{-2.118} f_1(\sigma)^{0.442}$ 38 0.95 0.2 RPB $M_1(MPa) = 38.28(w_a/w_i)^{-1.722}$ 88 0.95 0.3 RPB $M_1(MPa) = 4.085 \times 10^n (w_a/w_i)^{-1.99}$ 99 0.92 0.6 FWD $M_1(MPa) = 8.05 \times 10^n f_1(\sigma)^{0.464} (w_a/w_i)^{-1.97}$ 88 0.95 0.5 FWD $M_1(MPa) = 4.689 \times 10^{-1} f_1(\sigma)^{0.464} (w_a/w_i)^{-1.97}$ 88 0.96 0.4 FWD $M_1(MPa) = 2.97 \times 10^n f_1(\phi)^{-2.69} f_1(\sigma)^{0.355} (w_a/w_i)^{-1.97}$ 88 0.96 0.4 FWD $M_1(MPa) = 1.269 \times 10^n f_1(\phi)^{-2.69} f_1(\sigma)^{-2.99} f_1(\sigma)^{-2.99} f_1(\sigma)^{-2.99}$ 174 0.71 0.2 FWD $M_1(MPa) = 3.93 \times 10^n f_1(\psi)^{-2.69} f_1(\gamma)^{-2.99} f_1(\sigma)^{-2.99} f_$		0.00		07	0.00	۰
RPB $M_{\rm f}({\sf MPa}) = 3.021 \times 10^4 f(\psi)^{-3.266} f(\gamma)^{11.614} f_3(\sigma)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_{\rm f}({\sf MPa}) = 5.69 \times 10^4 f(\psi)^{-3.118} f_3(\sigma)^{0.317}$ 38 0.88 0.2 RPB $M_{\rm f}({\sf MPa}) = 2.405 \times 10^4 f(\psi)^{-2.918} f_3(\sigma)^{0.442}$ 38 0.84 0.2 Hart Brothers sand  Frozen FWD $M_{\rm f}({\sf MPa}) = 38.28(w_a/w_b)^{-1.732}$ 88 0.95 0.5 RPB $M_{\rm f}({\sf MPa}) = 4.085 \times 10^4 f(\psi)^{-2.918} f_3(\sigma)^{0.442}$ 88 0.95 0.4 FWD $M_{\rm f}({\sf MPa}) = 4.085 \times 10^4 f(\psi)^{-1.732}$ 88 0.95 0.5 RPB $M_{\rm f}({\sf MPa}) = 4.085 \times 10^4 f(\phi)^{-1.732} f_3(\sigma)^{0.45} (w_a/w_b)^{-1.79}$ 88 0.97 0.4 FWD $M_{\rm f}({\sf MPa}) = 4.085 \times 10^4 f(\phi)^{-1.08} f_3(\sigma)^{0.45} (w_a/w_b)^{-1.79}$ 88 0.96 0.4 FWD $M_{\rm f}({\sf MPa}) = 4.689 \times 10^{-7} f_3(\sigma)^{0.44} (w_a/w_b)^{-1.28}$ 88 0.96 0.4 FWD $M_{\rm f}({\sf MPa}) = 2.97 \times 10^7 f(\psi)^{-3.085} f_3(\sigma)^{0.453}$ 174 0.71 0.2 RPB $M_{\rm f}({\sf MPa}) = 3.99 \times 10^4 f(\psi)^{-3.095} f_3(\sigma)^{0.453}$ 174 0.87 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.99 \times 10^4 f(\psi)^{-3.095} f_3(\sigma)^{0.453}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f_3(\sigma)^{0.312}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f_3(\sigma)^{0.312}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.3.45 (w_a/w_b)^{-2.12}$ 69 0.95 0.6 Thawed FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^4 f(\psi)^{-1.712} f_3(\sigma)^{0.155}$ 64 0.65 0.2 Sibley till Frozen RPB $M_{\rm f}({\sf MPa}) = 1.01 \times 10^4 (w_a/w_b)^{-1.38} f_3(\sigma)^{0.1725}$ 64 0.65 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.01 \times 10^4 (w_a/w_b)^{-1.38} f_3(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.01 \times 10^4 (w_a/w_b)^{-1.38} f_3(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.01 \times 10^4 (w_a/w_b)^{-1.38} f_3(\sigma)^{0.1725}$	RPB $M_{f}(MPa) = 3.021 \times 10^{6} f(\psi)^{-3.266} f(\gamma)^{11.636} f_{s}(\sigma)^{0.442}$ 119 0.89 0.2 Recovered RPB $M_{f}(MPa) = 5.69 \times 10^{6} f(\psi)^{-3.118} f_{s}(\sigma)^{0.517}$ 38 0.88 0.2 RPB $M_{f}(MPa) = 2.405 \times 10^{6} f(\psi)^{-3.118} f_{s}(\sigma)^{0.517}$ 38 0.88 0.2 RPB $M_{f}(MPa) = 2.405 \times 10^{6} f(\psi)^{-2.918} f_{s}(\sigma)^{0.442}$ 38 0.84 0.2 RPB $M_{f}(MPa) = 38.28(w_{\sigma}/w_{\sigma})^{-1.722}$ 88 0.95 0.3 RPB $M_{f}(MPa) = 4.085 \times 10^{6} (w_{\sigma}/w_{\sigma})^{-1.59}$ 88 0.95 0.3 RPB $M_{f}(MPa) = 4.085 \times 10^{6} (w_{\sigma}/w_{\sigma})^{-1.59}$ 88 0.95 0.4 FWD $M_{f}(MPa) = 4.085 \times 10^{6} f(\sigma)^{0.565} (w_{\sigma}/w_{\sigma})^{-1.59}$ 88 0.96 0.4 FWD $M_{f}(MPa) = 4.689 \times 10^{7} f(\sigma)^{0.644} (w_{\sigma}/w_{\sigma})^{-1.28}$ 88 0.96 0.4 FWD $M_{f}(MPa) = 2.97 \times 10^{6} f(\psi)^{-3.095} f(\gamma)^{-3.095} f(\sigma)^{-0.453}$ 174 0.71 0.2 RPB $M_{f}(MPa) = 1.269 \times 10^{7} f(\psi)^{-3.095} f(\gamma)^{-3.095} f(\sigma)^{-0.453}$ 174 0.87 0.1 FWD $M_{f}(MPa) = 3.93 \times 10^{7} f(\psi)^{-2.87} f(\gamma)^{-3.19} f(\sigma)^{-0.453}$ 164 0.67 0.2 FWD $M_{f}(MPa) = 3.81 \times 10^{6} f(\psi)^{-2.817} f(\gamma)^{-3.17} f_{s}(\sigma)^{0.315}$ 164 0.67 0.2 FWD $M_{f}(MPa) = 3.81 \times 10^{6} f(\psi)^{-2.817} f(\gamma)^{-3.19} f_{s}(\sigma)^{0.315}$ 164 0.67 0.2 FWD $M_{f}(MPa) = 3.3.45(w_{\sigma}/w_{\sigma})^{-2.12}$ 69 0.95 0.6 Thawed FWD $M_{f}(MPa) = 7.147 \times 10^{6} f(\psi)^{-1.72} f_{s}(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_{f}(MPa) = 3.57 \times 10^{7} f(\psi)^{-1.72} f_{s}(\sigma)^{0.328}$ 61 0.74 0.1 Dease-graded stone FVD $M_{f}(MPa) = 1.56 \times 10^{7} f(\psi)^{-1.72} f_{s}(\sigma)^{0.328}$ 61 0.74 0.1 Pawed RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.72} f_{s}(\sigma)^{0.156}$ 64 0.65 0.2 Sibley till Frozen RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 64 0.65 0.2 RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 118 0.65 0.2 RPB $M_{f}(MPa) = 1.01 \times 10^{7} f(\psi)^{-1.329} f_{s}(\sigma)^{0.1725}$ 118 0.54 0.3 MM $f(\pi) = 1000 f(\pi)^{-1.12} f(\pi)^$	<b>77</b> 1		•			
Recovered RPB $M_{\rm f}({\rm MPa}) = 5.69 \times 10^4 f(\psi)^{-3.118} f_{\rm f}(o)^{0.537}$ 38 0.88 0.2 RPB $M_{\rm f}({\rm MPa}) = 2.405 \times 10^4 f(\psi)^{-2.918} f_{\rm f}(o)^{0.442}$ 38 0.84 0.2 Hart Brothers sand  Frozen FWD $M_{\rm f}({\rm MPa}) = 38.28 (w_u/w_s)^{-1.782}$ 88 0.95 0.5 RPB $M_{\rm f}({\rm MPa}) = 4.085 \times 10^4 (w_u/w_s)^{-1.59}$ 99 0.92 0.6 FWD $M_{\rm f}({\rm MPa}) = 8.05 \times 10^{-4} f_{\rm f}(o)^{0.464} (w_u/w_s)^{-1.99}$ 88 0.97 0.4 FWD $M_{\rm f}({\rm MPa}) = 4.689 \times 10^{-4} f_{\rm f}(o)^{0.464} (w_u/w_s)^{-1.38}$ 88 0.96 0.4 FWD $M_{\rm f}({\rm MPa}) = 4.689 \times 10^{-4} f_{\rm f}(o)^{0.464} (w_u/w_s)^{-1.38}$ 174 0.71 0.2 RPB $M_{\rm f}({\rm MPa}) = 1.269 \times 10^4 f(\psi)^{-3.099} f_{\rm f}(\gamma)^{3.023} f_{\rm f}(o)^{0.453}$ 174 0.71 0.2 RPB $M_{\rm f}({\rm MPa}) = 3.93 \times 10^4 f(\psi)^{-3.099} f_{\rm f}(\gamma)^{3.023} f_{\rm f}(o)^{0.453}$ 174 0.87 0.1 FWD $M_{\rm f}({\rm MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f_{\rm f}(\gamma)^{6.15} f_{\rm f}(o)^{0.457}$ 164 0.67 0.2 FWD $M_{\rm f}({\rm MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f_{\rm f}(\gamma)^{7.43} f_{\rm f}(o)^{0.375}$ 164 0.67 0.2 RPB $M_{\rm f}({\rm MPa}) = 3.345 (w_u/w_s)^{-2.03}$ 69 0.95 0.6 Thaved FWD $M_{\rm f}({\rm MPa}) = 3.57 \times 10^4 f(\psi)^{-1.792} f_{\rm f}(\sigma)^{0.364}$ 128 0.71 0.1 FWD $M_{\rm f}({\rm MPa}) = 3.57 \times 10^4 f(\psi)^{-1.792} f_{\rm f}(\sigma)^{0.362}$ 61 0.74 0.1 Dense-graded stone Frozen RPB $M_{\rm f}({\rm MPa}) = 82.27 (w_u/w_s)^{-2.03}$ 32 0.97 0.4 Thaved RPB $M_{\rm f}({\rm MPa}) = 1.56 \times 10^4 f(\psi)^{-1.379} f_{\rm f}(\sigma)^{0.345}$ 64 0.65 0.2 Sibley till Frozen RPB $M_{\rm f}({\rm MPa}) = 1.56 \times 10^4 f(\psi)^{-1.399} f_{\rm f}(\sigma)^{0.125}$ 64 0.65 0.2 RPB $M_{\rm f}({\rm MPa}) = 1.71 \times 10^4 f(\psi)^{-1.399} f_{\rm f}(\sigma)^{0.125}$ 118 0.63 0.2 RPB $M_{\rm f}({\rm MPa}) = 1.29 \times 10^4 f(\psi)^{-2.34}$ 118 0.63 0.2 RPB $M_{\rm f}({\rm MPa}) = 1.29 \times 10^4 f(\psi)^{-2.34}$ 118 0.63 0.2 RPB $M_{\rm f}({\rm MPa}) = 1.29 \times 10^4 f(\psi)^{-2.34}$ 118 0.54 0.3 M, = resilient modulus $\sigma_0 = 1  {\rm kPa}$ $m_{\rm f} = 1  {\rm k$	Recovered RPB $M_{t}(MPa) = 5.69 \times 10^{4} f(\psi)^{-3.118} f_{t}(\alpha)^{0.537}$ 38 0.88 0.2 RPB $M_{t}(MPa) = 2.405 \times 10^{4} f(\psi)^{-2.918} f_{t}(\alpha)^{0.442}$ 38 0.84 0.2 Hart Brothers sand  Frozen FWD $M_{t}(MPa) = 38.28(w_{u}/w_{t})^{-1.782}$ 88 0.95 0.5 RPB $M_{t}(MPa) = 4.085 \times 10^{4} (w_{u}/w_{t})^{-1.792}$ 88 0.95 0.5 FWD $M_{t}(MPa) = 8.05 \times 10^{4} f(\psi)^{-1.09} f_{t}(\alpha)^{0.454} (w_{u}/w_{t})^{-1.797}$ 88 0.97 0.4 FWD $M_{t}(MPa) = 4.085 \times 10^{4} f(w_{u}/w_{t})^{-1.797}$ 88 0.97 0.4 FWD $M_{t}(MPa) = 4.085 \times 10^{4} f(w_{u}/w_{t})^{-1.38}$ 88 0.96 0.4 FWD $M_{t}(MPa) = 1.269 \times 10^{4} f(\psi)^{-1.009} f(\psi)^{-1.009} f(\psi)^{-1.009} f(\alpha)^{-0.454} (w_{u}/w_{t})^{-1.797}$ 174 0.71 0.2 RPB $M_{t}(MPa) = 1.269 \times 10^{4} f(\psi)^{-1.009} f(\psi)^{-1.009} f(\psi)^{-0.237} f(\alpha)^{0.453}$ 174 0.87 0.1 FWD $M_{t}(MPa) = 3.81 \times 10^{4} f(\psi)^{-1.009} f(\psi)^{-1.009} f(\psi)^{-0.237}$ 164 0.67 0.2 FWD $M_{t}(MPa) = 3.81 \times 10^{4} f(\psi)^{-1.019} f(\psi)^{-1.019} f(\alpha)^{0.375}$ 164 0.67 0.2 RPB $M_{t}(MPa) = 3.81 \times 10^{4} f(\psi)^{-1.019} f(\psi)^{-1.019} f(\alpha)^{0.375}$ 164 0.67 0.2 RPB $M_{t}(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.244}$ 128 0.71 0.1 FWD $M_{t}(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.244}$ 128 0.71 0.1 Pawed RPB $M_{t}(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.244}$ 128 0.71 0.1 Pawed RPB $M_{t}(MPa) = 1.56 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.134}$ 64 0.65 0.2 RPB $M_{t}(MPa) = 7.147 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.134}$ 64 0.65 0.2 RPB $M_{t}(MPa) = 7.17 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 7.17 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.29 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.29 \times 10^{4} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.29 \times 10^{4} f(\psi)^{-1.019} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.01 \times 10^{4} f(\psi)^{-1.019} f(\psi)^{-1.019} f(\alpha)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.01 \times 10^{4} f(\psi)^{-1.019} f(\omega)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.01 \times 10^{4} f(\psi)^{-1.019} f(\omega)^{0.125}$ 118 0.63 0.2 RPB $M_{t}(M$	I nawed		• • • • • • • • • • • • • • • • • • • •			
Hart Brothers sand  Frozen  FWD $M_{t}(MPa) = 38.28(w_{u}/w_{t})^{-1.782}$ $88  0.95  0.5$ RPB $M_{t}(MPa) = 4.085 \times 10^{-1} f(\gamma_{t})^{-1.59}$ $99  0.92  0.6$ FWD $M_{t}(MPa) = 8.05 \times 10^{-1} f(\gamma_{t})^{-1.59}$ $99  0.92  0.6$ FWD $M_{t}(MPa) = 4.689 \times 10^{-1} f(\gamma_{t})^{-1.59}$ $88  0.97  0.4$ FWD $M_{t}(MPa) = 2.97 \times 10^{-1} f(\gamma_{t})^{-1.59} f(\gamma_{t})^{-1.39}$ RPB $M_{t}(MPa) = 1.269 \times 10^{-1} f(\gamma_{t})^{-1.303} f(\gamma_{t})^{-304} f_{t}(\sigma_{t})^{-0.451}$ RPB $M_{t}(MPa) = 1.269 \times 10^{-1} f(\psi_{t})^{-1.79} f(\psi_{t})^{-1.79} f(\sigma_{t})^{-0.451}$ FWD $M_{t}(MPa) = 3.99 \times 10^{-1} f(\psi_{t})^{-1.79} f(\gamma_{t})^{-0.29} f(\sigma_{t})^{-0.451}$ FWD $M_{t}(MPa) = 3.99 \times 10^{-1} f(\psi_{t})^{-2.51} f(\gamma_{t})^{-1.31} f(\sigma_{t})^{-0.452}$ FWD $M_{t}(MPa) = 3.81 \times 10^{-1} f(\psi_{t})^{-1.79} f(\sigma_{t})^{-0.23} f(\sigma_{t})^{-0.375}$ 164  0.67  0.2  Hyannis sand  Frozen  RPB $M_{t}(MPa) = 0.68 f(\gamma_{t})^{11.0} (w_{u}/w_{t})^{-2.12}$ 69  0.96  0.5  RPB $M_{t}(MPa) = 3.3.45(w_{u}/w_{t})^{-2.02}$ 69  0.95  0.6  Thawed  FWD $M_{t}(MPa) = 7.147 \times 10^{-1} f(\psi_{t})^{-1.792} f_{t}(\sigma_{t})^{0.362}$ 128  0.71  0.1  Dense-graded stose  Frozen  RPB $M_{t}(MPa) = 82.27(w_{u}/w_{t})^{-2.03}$ RPB $M_{t}(MPa) = 3.57 \times 10^{-1} f(\psi_{t})^{-1.792} f_{t}(\sigma_{t})^{0.362}$ RPB $M_{t}(MPa) = 7.17 \times 10^{-1} f(\psi_{t})^{-1.792} f_{t}(\sigma_{t})^{0.125}$ 64  0.65  0.2  RPB $M_{t}(MPa) = 7.17 \times 10^{-1} f(\psi_{t})^{-1.792} f_{t}(\sigma_{t})^{0.125}$ 18  0.8  NOTES:  RPB $M_{t}(MPa) = 1.01 \times 10^{1} (w_{u}/w_{t})^{-1.46}$ 108  0.87  0.7  Thawed  RPB $M_{t}(MPa) = 1.29 \times 10^{-1} f(\psi_{t})^{-1.396} f_{t}(\sigma_{t})^{-1.12}$ 118  0.54  0.3  NOTES:  RPB $M_{t}(MPa) = 1.29 \times 10^{-1} f(\psi_{t})^{-1.264}$ 118  0.54  0.3  NOTES:  RPB $M_{t}(MPa) = 1.29 \times 10^{-1} f(\psi_{t})^{-1.264}$ 118  0.54  0.3	Hart Brothers sand  Frozen  FWD $M_{t}(MPa) = 38.28(w_{u}/w_{t})^{-1.782}$ $RPB$ $M_{t}(MPa) = 38.28(w_{u}/w_{t})^{-1.782}$ $RPB$ $M_{t}(MPa) = 4.085 \times 10^{-1} (h_{u}/w_{t})^{-1.99}$ $M_{t}(MPa) = 4.085 \times 10^{-1} (h_{u}/w_{t})^{-1.99}$ $M_{t}(MPa) = 8.05 \times 10^{-1} f_{t}/q_{d})^{-0.44} f_{t}(0)^{0.345} (w_{u}/w_{t})^{-1.97}$ $M_{t}(MPa) = 8.05 \times 10^{-1} f_{t}/q_{d})^{-0.44} f_{t}(0)^{0.345} (w_{u}/w_{t})^{-1.97}$ $M_{t}(MPa) = 4.689 \times 10^{-1} f_{t}/q_{d})^{-0.44} f_{t}(0)^{0.345} (w_{u}/w_{t})^{-1.39}$ $M_{t}(MPa) = 2.97 \times 10^{-1} f_{t}/q_{d})^{-0.44} f_{t}/q_{d}$ $M_{t}(MPa) = 1.269 \times 10^{-3} f_{t}/q_{d})^{-0.44} f_{t}/q_{d}}/q_{d}$ $M_{t}(MPa) = 1.269 \times 10^{-3} f_{t}/q_{d})^{-0.44} f_{t}/q_{d}}/q_{d}$ $M_{t}(MPa) = 3.93 \times 10^{-3} f_{t}/q_{d})^{-0.49} f_{t}/q_{d}}/q_{d}$ $M_{t}(MPa) = 3.81 \times 10^{-5} f_{t}/q_{d}}/q_{d}/q_{d}}/q_{d}/q_{d}}/q_{d}/q_{d}}/q_{d}/q_{d}/q_{d}/q_{d}}/q_{d}/$	Passyanad		• • • • • • • • • • • • • • • • • • • •			
Frozen FWD $M_r(MPa) = 38.28(w_q/w_r)^{-1.782}$ 88 0.95 0.5 RPB $M_r(MPa) = 4.085 \times 10^{1} (w_q/w_r)^{-1.59}$ 99 0.92 0.6 FWD $M_r(MPa) = 4.085 \times 10^{1} (\gamma_q/w_r)^{-1.59}$ 88 0.97 0.4 FWD $M_r(MPa) = 8.05 \times 10^{-1} f(\gamma_f)^{-2.64} f(\gamma_f)^{-0.365} (w_q/w_r)^{-1.97}$ 88 0.97 0.4 FWD $M_r(MPa) = 4.689 \times 10^{-1} f(\gamma_f)^{-2.64} f(\gamma_g/w_r)^{-1.38}$ 88 0.96 0.4 FWD $M_r(MPa) = 1.269 \times 10^{-1} f(\psi_r)^{-3.08} f(\gamma_f)^{-3.08} f(\gamma_f)^{-3.08} f(\gamma_f)^{-3.08}$ 174 0.71 0.2 RPB $M_r(MPa) = 1.269 \times 10^{-1} f(\psi_r)^{-3.08} f(\gamma_f)^{-3.08} f(\gamma_f)^{-6.51}$ 174 0.87 0.1: FWD $M_r(MPa) = 3.93 \times 10^{-1} f(\psi_r)^{-3.08} f(\gamma_f)^{-3.08} f(\gamma_f)^{-6.51}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^{-1} f(\psi_r)^{-2.817} f(\gamma_f)^{-1.19} f(\gamma_f)^{-3.15}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^{-1} f(\psi_r)^{-2.817} f(\gamma_f)^{-3.15} f(\gamma_f)^{-3.15}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.845(w_q/w_r)^{-2.07}$ 169 0.95 0.6 Thawed FWD $M_r(MPa) = 3.345(w_q/w_r)^{-2.09}$ 169 0.96 0.5 O.5 FWD $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26} f(\gamma_f)^{-3.26}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26}$ 127 0.1 FWD $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26}$ 129 0.97 0.4 O.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 1.56 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26}$ 129 0.97 0.4 O.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 1.56 \times 10^{-1} f(\psi_r)^{-1.72} f_r(\gamma_f)^{-3.26}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} (w_q/w_r)^{-3.26} f_r(\gamma_f)^{-3.26}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} f(\psi_r)^{-3.26} f_r(\gamma_f)^{-3.26}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} f(\psi_r)^{-3.26} f_r(\gamma_f)^{-3.26}$ 118 0.54 0.3 M $r_r = resilient modulus$ $\sigma_0 = 1 Pa$ $\sigma_0 = 1 Pa$ 118 0.54 0.3 M $r_r = resilient modulus$ $\sigma_0 = 1 Pa$ $w_r = unfrozen water content$ $\sigma_0 = 1 Pa$ $\sigma$	Frozen FWD $M_r(MPa) = 38.28(w_q/w_r)^{-1.782}$ 88 0.95 0.0 RPB $M_r(MPa) = 4.085 \times 10^{1} (w_q/w_r)^{-1.59}$ 99 0.92 0.6 FWD $M_r(MPa) = 4.085 \times 10^{1} (\gamma_q/w_r)^{-1.59}$ 88 0.97 0.4 FWD $M_r(MPa) = 8.05 \times 10^{-1} f(\gamma_f)^{-2.44} (w_q/w_r)^{-1.37}$ 88 0.96 0.4 FWD $M_r(MPa) = 4.689 \times 10^{-1} f(\gamma_f)^{-2.44} (w_q/w_r)^{-1.38}$ 88 0.96 0.4 FWD $M_r(MPa) = 1.269 \times 10^{-1} f(\psi_r)^{-3.08} f(\gamma_f)^{-3.86} f(\sigma_f)^{-6.45}$ 174 0.87 0.1 FWD $M_r(MPa) = 1.269 \times 10^{-1} f(\psi_r)^{-3.08} f(\gamma_f)^{-3.86} f(\sigma_f)^{-6.45}$ 174 0.87 0.1 FWD $M_r(MPa) = 3.93 \times 10^{-1} f(\psi_r)^{-2.67} f(\gamma_f)^{-1.19} f(\sigma_f)^{-6.45}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^{-1} f(\psi_r)^{-2.47} f(\gamma_f)^{-1.19} f(\sigma_f)^{-6.45}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^{-1} f(\psi_r)^{-2.47} f(\gamma_f)^{-3.17} f(\sigma_f)^{-3.17}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.345(w_q/w_r)^{-2.02}$ 69 0.96 0.5 Thawed FWD $M_r(MPa) = 3.345(w_q/w_r)^{-2.02}$ 69 0.96 0.5 FWD $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_f)^{-1.72} f_r(\sigma_f)^{-0.342}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_f)^{-1.72} f_r(\sigma_f)^{-1.52}$ 64 0.65 0.2 RPB $M_r(MPa) = 3.57 \times 10^{-1} f(\psi_f)^{-1.72} f_r(\sigma_f)^{-1.72}$ 64 0.65 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} (w_q/w_r)^{-2.03}$ 32 0.97 0.4 RPB $M_r(MPa) = 1.01 \times 10^{-1} (w_q/w_r)^{-3.09}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} (w_q/w_r)^{-3.49}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.01 \times 10^{-1} (w_q/w_r)^{-3.49}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^{-7} f(\psi_f)^{-3.29} f_r(\sigma_f)^{-3/2}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^{-7} f(\psi_f)^{-3.29} f_r(\sigma_f)^{-3/2}$ 118 0.54 0.3 M $m_r$ = resilient modulus $\sigma_0 = 1 \text{ kPa}$ $w_q = \text{unifrozen water content}$ $w_q = unifrozen $	Recovered		• • • • • • • • • • • • • • • • • • • •			
Frozen FWD $M_f(\text{MPa}) = 38.28(w_f/w_f)^{-1.782}$ 88 0.95 0.3 RPB $M_f(\text{MPa}) = 4.085 \times 10^4 (w_g/w_f)^{-1.99}$ 99 0.92 0.66 FWD $M_f(\text{MPa}) = 4.085 \times 10^4 (w_g/w_f)^{-1.99}$ 88 0.97 0.4 FWD $M_f(\text{MPa}) = 4.085 \times 10^4 f_f(\sigma)^{0.345} f_f(\sigma)^{0.345} (w_g/w_f)^{-1.97}$ 88 0.97 0.4 FWD $M_f(\text{MPa}) = 4.089 \times 10^4 f_f(\sigma)^{0.444} (w_g/w_f)^{-1.97}$ 88 0.96 0.4 FWD $M_f(\text{MPa}) = 4.089 \times 10^4 f_f(\sigma)^{0.444} (w_g/w_f)^{-1.97}$ 174 0.71 0.2 RPB $M_f(\text{MPa}) = 1.269 \times 10^4 f_f(\sigma)^{0.444} (w_g/w_f)^{-1.93} f_f(\sigma)^{0.453}$ 174 0.87 0.11 FWD $M_f(\text{MPa}) = 1.269 \times 10^4 f_f(\sigma)^{-2.67} f_f(\sigma)^{0.457}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.99 \times 10^4 f_f(\sigma)^{-2.67} f_f(\sigma)^{0.457}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.67} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.17} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.17} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.17} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.17} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-2.17} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-1.72} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-1.72} f_f(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(\sigma)^{-1.72} f_f(\sigma)^{0.345}$ 128 0.71 0.1 FWD $M_f(\text{MPa}) = 3.57 \times 10^4 f_f(\sigma)^{-1.325} f_f(\sigma)^{0.325}$ 128 0.71 0.1 FWD $M_f(\text{MPa}) = 3.57 \times 10^4 f_f(\sigma)^{-1.325} f_f(\sigma)^{0.325}$ 128 0.71 0.1 FWD $M_f(\text{MPa}) = 1.01 \times 10^4 f_f(\sigma)^{-1.325} f_f(\sigma)^{0.325}$ 130 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0	Frozen FWD $M_f(\text{MPa}) = 38.28(w_g/w_f)^{-1.782}$ 88 0.95 0.3 RPB $M_f(\text{MPa}) = 4.085 \times 10^4 (w_g/w_f)^{-1.99}$ 99 0.92 0.6 FWD $M_f(\text{MPa}) = 4.085 \times 10^4 (w_g/w_f)^{-1.99}$ 88 0.97 0.4 FWD $M_f(\text{MPa}) = 4.085 \times 10^4 f_f(q)^{0.484} (w_g/w_f)^{-1.97}$ 88 0.97 0.4 FWD $M_f(\text{MPa}) = 4.089 \times 10^{-4} f_f(q)^{0.484} (w_g/w_f)^{-1.97}$ 88 0.96 0.4 FWD $M_f(\text{MPa}) = 4.089 \times 10^{-4} f_f(q)^{0.484} (w_g/w_f)^{-1.99}$ 174 0.71 0.2 RPB $M_f(\text{MPa}) = 4.089 \times 10^{-4} f_f(q)^{0.484} (w_g/w_f)^{-1.99}$ 174 0.87 0.1 FWD $M_f(\text{MPa}) = 4.089 \times 10^{-4} f_f(q)^{0.485} f_f(q)^{0.453}$ 174 0.87 0.1 FWD $M_f(\text{MPa}) = 1.269 \times 10^4 f_f(q)^{-1.089} f_f(q)^{7.023} f_f(q)^{0.453}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.93 \times 10^4 f_f(q)^{-2.817} f_f(q)^{0.437}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(q)^{-2.817} f_f(q)^{0.437}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 3.81 \times 10^4 f_f(q)^{-2.817} f_f(q)^{0.375}$ 164 0.67 0.2 FWD $M_f(\text{MPa}) = 33.45(w_g/w_f)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_f(\text{MPa}) = 33.45(w_g/w_f)^{-2.03}$ 69 0.95 0.6 FWD $M_f(\text{MPa}) = 31.47 \times 10^4 f_f(q)^{-1.782} f_f(q)^{0.3628}$ 61 0.74 0.1 FWD $M_f(\text{MPa}) = 3.57 \times 10^4 f_f(q)^{-1.276} f_f(q)^{0.3628}$ 61 0.74 0.1 FWD $M_f(\text{MPa}) = 1.56 \times 10^4 f_f(q)^{-1.782} f_f(q)^{0.3628}$ 64 0.65 0.2 RPB $M_f(\text{MPa}) = 1.56 \times 10^4 f_f(q)^{-1.782} f_f(q)^{0.3628}$ 64 0.65 0.2 RPB $M_f(\text{MPa}) = 7.47 \times 10^4 f_f(q)^{-1.782} f_f(q)^{0.1725}$ 64 0.65 0.2 RPB $M_f(\text{MPa}) = 1.01 \times 10^4 (w_g/w_f)^{-1.982} f_f(q)^{0.1725}$ 118 0.63 0.7 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.389} f_f(q)^{0.1725}$ 118 0.54 0.3 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.389} f_f(q)^{0.192}$ 118 0.54 0.3 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.282} f_f(q)^{0.192}$ 118 0.54 0.3 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.282} f_f(q)^{0.192}$ 118 0.54 0.3 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.282} f_f(q)^{0.192}$ 118 0.54 0.3 RPB $M_f(\text{MPa}) = 1.29 \times 10^4 f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} f_f(q)^{-1.282} $	Hart Brothers can		$M_{\Gamma}(ML\Delta) = 2.403 \times 10^{-3} (\phi)$	30	0.04	0.2.
RPB $M_{t}(MPa) = 4.085 \times 10^{-1} (w_{u}/w_{t})^{-1.59}$ 99 0.92 0.6 FWD $M_{t}(MPa) = 8.05 \times 10^{-1} f(\gamma_{d})^{-64} f_{t}(\sigma)^{0.365} (w_{u}/w_{t})^{-1.97}$ 88 0.97 0.4 FWD $M_{t}(MPa) = 4.689 \times 10^{-1} f_{t}(\sigma)^{-644} (w_{u}/w_{t})^{-1.38}$ 88 0.96 0.4 Thawed RPB $M_{t}(MPa) = 1.269 \times 10^{-1} f_{t}(\sigma)^{-645} f_{t}(\sigma)^{0.455}$ 174 0.71 0.2 RPB $M_{t}(MPa) = 1.269 \times 10^{-1} f_{t}(\sigma)^{-1.305} f_{t}(\sigma)^{-0.455}$ 174 0.87 0.1: FWD $M_{t}(MPa) = 3.93 \times 10^{-4} f_{t}(\psi)^{-1.399} f_{t}(\gamma)^{-1.02} f_{t}(\sigma)^{0.457}$ 164 0.67 0.2: FWD $M_{t}(MPa) = 3.81 \times 10^{-4} f_{t}(\psi)^{-2.817} f_{t}(\gamma)^{7.43} f_{t}(\sigma)^{0.375}$ 164 0.67 0.2: Hyannis sand Frozen RPB $M_{t}(MPa) = 3.3.45 (w_{u}/w_{t})^{-2.01}$ 69 0.96 0.5 RPB $M_{t}(MPa) = 3.3.45 (w_{u}/w_{t})^{-2.01}$ 69 0.95 0.6 Thawed FWD $M_{t}(MPa) = 3.3.45 (w_{u}/w_{t})^{-2.02}$ 128 0.71 0.1: FWD $M_{t}(MPa) = 3.57 \times 10^{-7} f_{t}(\psi)^{-1.372} f_{t}(\sigma)^{0.3628}$ 128 0.71 0.1: Dense-graded stone Frozen RPB $M_{t}(MPa) = 82.27 (w_{u}/w_{t})^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_{t}(MPa) = 1.56 \times 10^{-7} f_{t}(\psi)^{-1.369} f_{t}(\sigma)^{0.156}$ 64 0.65 0.2 RPB $M_{t}(MPa) = 7.17 \times 10^{-7} f_{t}(\psi)^{-1.359} f_{t}(\sigma)^{0.1725}$ 64 0.65 0.2 Sibbey till  Frozen RPB $M_{t}(MPa) = 1.01 \times 10^{12} (w_{u}/w_{t})^{-3.466}$ 108 0.87 0.7 Thawed RPB $M_{t}(MPa) = 7.47 \times 10^{-7} f_{t}(\psi)^{-1.359} f_{t}(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_{t}(MPa) = 1.29 \times 10^{-7} f_{t}(\psi)^{-2.144}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform $\theta_{0} = 1^{-1}C$ $\pi = \text{number of points}$ $f_{t}(\sigma) = [(f_{t}/\tau_{oct})/\sigma_{ot}]$ $f_{t}(\psi) = f_{t}(101.38-\psi)/\psi_{ot}]$ $\psi_{0} = 1 \text{ kPa}$ $\psi_{0} = 1 \text$	RPB $M_{\rm f}({\sf MPa}) = 4.085 \times 10^{-1} (w_u/w_t)^{-1.59}$ 99 0.92 0.6 FWD $M_{\rm f}({\sf MPa}) = 8.05 \times 10^{-1} f/q_0^{1/46} f_1(\sigma)^{0.365} (w_u/w_t)^{-1.97}$ 88 0.97 0.4 FWD $M_{\rm f}({\sf MPa}) = 4.689 \times 10^{-1} f/(q_0^{1/46} f_1(\sigma)^{0.365} (w_u/w_t)^{-1.97}$ 88 0.97 0.4 FWD $M_{\rm f}({\sf MPa}) = 2.97 \times 10^{5} f(\psi)^{-3.095} f(\gamma)^{7.596} f_1(\sigma)^{0.453}$ 174 0.71 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.269 \times 10^{7} f(\psi)^{-3.095} f(\gamma)^{7.023} f_1(\sigma)^{0.453}$ 174 0.87 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.93 \times 10^{6} f(\psi)^{-1.09} f(\gamma)^{7.023} f_1(\sigma)^{0.457}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.81 \times 10^{6} f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.81 \times 10^{6} f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_{\rm f}({\sf MPa}) = 3.3.45 (w_u/w_t)^{-2.03}$ 69 0.95 0.5 RPB $M_{\rm f}({\sf MPa}) = 3.3.45 (w_u/w_t)^{-2.03}$ 69 0.95 0.5 PWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^{7} f(\psi)^{-1.782} f_1(\sigma)^{0.364}$ 128 0.71 0.1 FWD $M_{\rm f}({\sf MPa}) = 3.57 \times 10^{7} f(\psi)^{-1.372} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone Frozen RPB $M_{\rm f}({\sf MPa}) = 82.27 (w_u/w_t)^{-2.03}$ 32 0.97 0.4 RPB $M_{\rm f}({\sf MPa}) = 1.56 \times 10^{7} f(\psi)^{-1.76} f_1(\sigma)^{0.156}$ 64 0.65 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.56 \times 10^{7} f(\psi)^{-1.369} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.01 \times 10^{10} (w_u/w_t)^{-3.466}$ 108 0.87 0. Thawed RPB $M_{\rm f}({\sf MPa}) = 7.47 \times 10^{6} f(\psi)^{-1.569} f_1(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.63 0.2 RPB $M_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 PRPB $M_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.44}$ 118 0.54 0.3 FWD $m_{\rm f}({\sf MPa}) = 1.29 $			$M_{\cdot}(MPa) = 38.28(w_{\cdot}/w_{\cdot})^{-1.782}$	88	0.95	0.5
FWD $M_t(MPa) = 8.05 \times 10^{-1} f_{1/3})^{7.64} f_{1}(\sigma)^{0.365} (w_{o}/w_{t})^{-1.97}$ 88 0.97 0.4 FWD $M_t(MPa) = 4.689 \times 10^{-1} f_{1}(\sigma)^{0.464} (w_{o}/w_{t})^{-1.36}$ 88 0.96 0.4 RPB $M_t(MPa) = 2.97 \times 10^{9} f_{t}(\psi)^{-1.063} f_{t}(\gamma)^{5.365} f_{t}(\sigma)^{6.453}$ 174 0.71 0.2 RPB $M_t(MPa) = 1.269 \times 10^{9} f_{t}(\psi)^{-1.089} f_{t}(\gamma)^{0.23} f_{t}(\sigma)^{0.453}$ 174 0.87 0.1 FWD $M_t(MPa) = 3.93 \times 10^{9} f_{t}(\psi)^{-1.089} f_{t}(\gamma)^{0.23} f_{t}(\sigma)^{0.457}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.81 \times 10^{9} f_{t}(\psi)^{-1.089} f_{t}(\gamma)^{0.437}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.81 \times 10^{9} f_{t}(\psi)^{-1.07} f_{t}(\gamma)^{0.43} f_{t}(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.81 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\gamma)^{0.43} f_{t}(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_t(MPa) = 3.3.45 (w_{o}/w_{t})^{-2.03}$ 69 0.96 0.5 RPB $M_t(MPa) = 3.57 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_t(MPa) = 3.57 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone FYOD $M_t(MPa) = 3.57 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone FYOD $M_t(MPa) = 1.56 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\sigma)^{0.3628}$ 62 0.9 0.9 0.6 Subley till FYOZEN RPB $M_t(MPa) = 1.56 \times 10^{9} f_{t}(\psi)^{-1.72} f_{t}(\sigma)^{0.156}$ 64 0.65 0.2 RPB $M_t(MPa) = 7.17 \times 10^{9} f_{t}(\psi)^{-1.739} f_{t}(\sigma)^{0.1725}$ 65 0.0 Subley till FYOZEN RPB $M_t(MPa) = 1.01 \times 10^{10} (w_{o}/w_{o})^{-1.39} f_{t}(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_t(MPa) = 1.29 \times 10^{9} f_{t}(\psi)^{-1.244}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform $g_{o} = 1 \text{ kPa}$ $g_{$	FWD $M_t(MPa) = 8.05 \times 10^{-1} f_{1/2})^{7.64} f_{1}(\sigma)^{0.365} (w_u/w_t)^{-1.37}$ FWD $M_t(MPa) = 4.689 \times 10^{-1} f_{1}(\sigma)^{0.444} (w_u/w_t)^{-1.36}$ 88 0.96 0.4  Thawed RPB $M_t(MPa) = 2.97 \times 10^{9} f(\psi)^{-1.083} f(\gamma)^{5.396} f_{1}(\sigma)^{6.451}$ 174 0.71 0.2  RPB $M_t(MPa) = 1.269 \times 10^{1} f(\psi)^{-1.089} f(\gamma)^{7.233} f_{1}(\sigma)^{0.453}$ 174 0.87 0.1  FWD $M_t(MPa) = 3.93 \times 10^{4} f(\psi)^{-1.099} f(\gamma)^{7.023} f_{1}(\sigma)^{0.451}$ 164 0.67 0.2  FWD $M_t(MPa) = 3.81 \times 10^{4} f(\psi)^{-1.099} f(\gamma)^{7.43} f_{1}(\sigma)^{0.457}$ 164 0.67 0.2  FWD $M_t(MPa) = 3.81 \times 10^{4} f(\psi)^{-1.07} f(\gamma)^{7.43} f_{1}(\sigma)^{0.375}$ 164 0.67 0.2  Hyannis sand  Frozen RPB $M_t(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5  RPB $M_t(MPa) = 33.45 (w_t/w_t)^{-2.03}$ 69 0.95 0.6  Thawed FWD $M_t(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.742} f_{1}(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_t(MPa) = 3.57 \times 10^{4} f(\psi)^{-1.742} f_{1}(\sigma)^{0.264}$ 128 0.71 0.1  Dense-graded stone  Frozen RPB $M_t(MPa) = 82.27 (w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_t(MPa) = 1.56 \times 10^{5} f(\psi)^{-1.36} f_{1}(\sigma)^{0.156}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_t(MPa) = 1.01 \times 10^{4} (w_u/w_t)^{-1.36} f_{1}(\sigma)^{0.1725}$ 65 0.5  Sibley till  Frozen RPB $M_t(MPa) = 1.01 \times 10^{4} (w_u/w_t)^{-1.46}$ 108 0.87 0.  Thawed RPB $M_t(MPa) = 1.29 \times 10^{4} f(\psi)^{-1.244}$ 118 0.63 0.2  RPB $M_t(MPa) = 1.29 \times 10^{4} f(\psi)^{-1.244}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $g_0 = 1 \times C$ $f(\psi) = 1 \times C$ $f($	1100011		15 7			
Thawed RPB $M_r(MPa) = 4.689 \times 10^{-1} f_1(\sigma)^{0.444} (w_u/w_t)^{-1.38}$ 88 0.96 0.48  Thawed RPB $M_r(MPa) = 2.97 \times 10^3 f(\psi)^{-3.063} f(\gamma)^{5.966} f_1(\sigma)^{0.433}$ 174 0.71 0.22  RPB $M_r(MPa) = 1.269 \times 10^3 f(\psi)^{-3.069} f(\gamma)^{-2.03} f_1(\sigma)^{0.433}$ 174 0.87 0.13  FWD $M_r(MPa) = 3.93 \times 10^4 f(\psi)^{-2.67} f(\gamma)^{6.18} f_1(\sigma)^{0.457}$ 164 0.67 0.22  FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{3.43} f_1(\sigma)^{0.375}$ 164 0.67 0.22  Hyanais sand  Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5  RPB $M_r(MPa) = 33.45(w_u/w_t)^{-2.09}$ 69 0.95 0.6  Thawed FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.3628}$ 61 0.74 0.11  Dense-graded stone  Frozen RPB $M_r(MPa) = 1.56 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.156}$ 64 0.65 0.2  RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.78} f_1(\sigma)^{0.116}$ 64 0.65 0.2  RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^4 (w_u/w_t)^{-2.44}$ 118 0.63 0.2  RPB $M_r(MPa) = 1.29 \times 10^4 f(\psi)^{-2.44}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $n = \text{number of points}$ $f_1(\sigma) = [(f_1/\tau_{0ct})/\sigma_0]$ $f(\psi) = [(101.38 + \psi)/\psi_o]$ $\psi_o = 1 \text{ kPa}$ $f_1(\sigma) = (f_1/\sigma_o)$ $w_1 = \text{total water content}$ $f_1(\tau) = \gamma/\gamma_o$ $f(\tau) = 1 \text{ mg/m}^2$	Thawed RPB $M_r(MPa) = 4.689 \times 10^{-1} f_1(\sigma)^{0.444} (w_u/w_t)^{-1.38}$ 88 0.96 0.4  RPB $M_r(MPa) = 2.97 \times 10^3 f(\psi)^{-3.083} f_1(\gamma)^{5.946} f_2(\sigma)^{0.453}$ 174 0.71 0.2  RPB $M_r(MPa) = 1.269 \times 10^3 f(\psi)^{-3.089} f_1(\gamma)^{-0.33} f_1(\sigma)^{0.433}$ 174 0.87 0.1  FWD $M_r(MPa) = 3.93 \times 10^4 f(\psi)^{-2.67} f_1(\gamma)^{0.18} f_1(\sigma)^{0.457}$ 164 0.67 0.2  FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f_1(\gamma)^{1.43} f_1(\sigma)^{0.457}$ 164 0.67 0.2  Hyannis sand  Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5  RPB $M_r(MPa) = 33.45(w_u/w_t)^{-2.09}$ 69 0.95 0.6  Thawed FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.792} f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_r(MPa) = 1.56 \times 10^4 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^{12} (w_u/w_t)^{-3.446}$ 108 0.87 0.  Thawed RPB $M_r(MPa) = 1.01 \times 10^{12} (w_u/w_t)^{-3.446}$ 108 0.87 0.  NOTES:  RPB $M_r(MPa) = 1.29 \times 10^4 f(\psi)^{-2.44}$ 118 0.54 0.3  NOTES:  RPB repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $\pi$ = number of points $f_1(\sigma) = (f_1/\sigma_{00})$ $w_1$ = total water content $f_1(\sigma) = (f_1/\sigma_{00})$ $w_1$ = total water content $f_1(\sigma) = (f_1/\sigma_{00})$ $w_1$ = total water content $f_1(\sigma) = (f_1/\sigma_{00})$ $y_0 = 1 \text{ mg/m}^2$						0.44
Thawed RPB $M_r(\text{MPa}) = 2.97 \times 10^3 f(\psi)^{-3.063} f(\gamma)^{5.966} f_1(\sigma)^{0.453}$ 174 0.71 0.22 RPB $M_r(\text{MPa}) = 1.269 \times 10^3 f(\psi)^{-3.069} f(\gamma)^{7.023} f_1(\sigma)^{0.453}$ 174 0.87 0.13 FWD $M_r(\text{MPa}) = 3.93 \times 10^4 f(\psi)^{-2.617} f(\gamma)^{6.18} f_r(\sigma)^{0.457}$ 164 0.67 0.22 FWD $M_r(\text{MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.22 FWD $M_r(\text{MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.22 RPB $M_r(\text{MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 169 0.95 0.6 RPB $M_r(\text{MPa}) = 3.3.45 (w_u/w_l)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_r(\text{MPa}) = 3.3.45 (w_u/w_l)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_r(\text{MPa}) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.3628}$ 61 0.74 0.11 Power graded stose Frozen RPB $M_r(\text{MPa}) = 82.27 (w_u/w_l)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^3 f(\psi)^{-1.56} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(\text{MPa}) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 108 0.87 0.5 Sibley till Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^{12} (w_u/w_r)^{-3.466}$ 108 0.87 0.7 Thawed RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.63 0.2 RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform FWD = falling weight deflectometer waveform $\sigma = 0.00 = 1 \text{ NC}$ $\sigma = 1.00 = 1$	Thawed RPB $M_r(MPa) = 2.97 \times 10^3 f(\psi)^{-3.085} f(\gamma)^{-3.98} f_1(\sigma)^{0.433}$ 174 0.71 0.2 RPB $M_r(MPa) = 1.269 \times 10^3 f(\psi)^{-3.089} f(\gamma)^{7.023} f_1(\sigma)^{0.433}$ 174 0.87 0.1 FWD $M_r(MPa) = 3.93 \times 10^4 f(\psi)^{-2.67} f(\gamma)^{6.18} f_1(\sigma)^{0.437}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 RPB $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 169 0.96 0.5 RPB $M_r(MPa) = 3.3.45 (w_u/w_l)^{-2.03}$ 69 0.95 0.6 FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stose Frozen RPB $M_r(MPa) = 82.27 (w_u/w_l)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^3 f(\psi)^{-1.58} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.64 0.5  0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.54 0.3 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 119 0.5				88		0.4
RPB $M_r(MPa) = 1.269 \times 10^3 f(\psi)^{-3.089} f_1(\sigma)^{0.0453}$ 174 0.87 0.11 FWD $M_r(MPa) = 3.93 \times 10^4 f(\psi)^{-2.67} f_1(\gamma)^{6.18} f_1(\sigma)^{0.457}$ 164 0.67 0.22 FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f_1(\gamma)^{7.43} f_2(\sigma)^{0.375}$ 164 0.67 0.22 Hyannis sand  Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_i)^{-2.12}$ 69 0.96 0.5 RPB $M_r(MPa) = 33.45(w_u/w_i)^{-2.09}$ 69 0.95 0.6 Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.742} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-1.282} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-1.292} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 1.56 \times 10^9 f(\psi)^{-1.762} f_1(\sigma)^{0.156}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.762} f_1(\sigma)^{0.156}$ 64 0.65 0.2 RPB $M_r(MPa) = 1.01 \times 10^4 (w_u/w_i)^{-2.09}$ 108 0.87 0.7 Thawed RPB $M_r(MPa) = 1.01 \times 10^4 (w_u/w_i)^{-3.466}$ 108 0.87 0.7 Thawed RPB $M_r(MPa) = 1.01 \times 10^4 (w_u/w_i)^{-3.466}$ 108 0.87 0.7 Thawed RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.56} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.56}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ $\theta_0 = 1^{-C}$ $f(\psi) = 1 PC$ $\theta_0 =$	RPB $M_r(MPa) = 1.269 \times 10^3 f(\psi)^{-3.089} f_1(\sigma)^{0.0453}$ 174 0.87 0.1 FWD $M_r(MPa) = 3.93 \times 10^4 f(\psi)^{-2.67} f_1(\gamma)^{6.18} f_1(\sigma)^{0.457}$ 164 0.67 0.2 FWD $M_r(MPa) = 3.81 \times 10^4 f(\psi)^{-2.817} f_1(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 Hyannis sand  Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_i)^{-2.12}$ 69 0.96 0.5 RPB $M_r(MPa) = 33.45 (w_u/w_i)^{-2.09}$ 69 0.95 0.6 Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 82.27 (w_u/w_i)^{-2.09}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^5 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^{12} (w_u/w_i)^{-3.466}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 1.01 \times 10^{12} (w_u/w_i)^{-3.466}$ 108 0.87 0. RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.46}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.46}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform FWD = falling weight deflectometer waveform $m_r = n$ number of points $m_r = n$ find wave frequency $m_r = n$ unfrozen water content $m_r = n$ in $m_r = n$ $m$	Thawed	RPB		174	0.71	0.2
FWD $M_{\rm f}({\rm MPa}) = 3.81 \times 10^4 \ f(\psi)^{-2.817} \ f(\gamma)^{7.43} \ f_1(\sigma)^{0.375}$ 164 0.67 0.2 Hyannis sand  Frozen RPB $M_{\rm f}({\rm MPa}) = 0.68 \ f(\gamma)^{11.0} \ (w_u/w_t)^{-2.12}$ 69 0.96 0.5  RPB $M_{\rm f}({\rm MPa}) = 33.45 \ (w_u/w_t)^{-2.03}$ 69 0.95 0.6  Thawed FWD $M_{\rm f}({\rm MPa}) = 7.147 \times 10^4 \ f(\psi)^{-1.782} \ f_1(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_{\rm f}({\rm MPa}) = 3.57 \times 10^7 \ f(\psi)^{-3.276} \ f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_{\rm f}({\rm MPa}) = 82.27 \ (w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_{\rm f}({\rm MPa}) = 1.56 \times 10^5 \ f(\psi)^{-1.76} \ f_1(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_{\rm f}({\rm MPa}) = 7.17 \times 10^6 \ f(\psi)^{-1.589} \ f_1(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_{\rm f}({\rm MPa}) = 1.01 \times 10^2 \ (w_u/w_t)^{-3.466}$ 108 0.87 0.7  Thawed RPB $M_{\rm f}({\rm MPa}) = 7.47 \times 10^6 \ f(\psi)^{2.829} \ f_1(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_{\rm f}({\rm MPa}) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \ {}^{\circ}{\rm C}$ $m = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{\rm oct})/\sigma_0]$ $f_1(\psi) = (101.38 - \psi)/\psi_0]$ $M_{\rm f} = \text{resilient modulus}$ $\sigma_0 = 1 \ {}^{\circ}{\rm KP}$ $\theta_1({\rm cot}) = 1 \ {}^{\circ}{\rm KP}$ $\theta_2({\rm cot}) = 1 \ {}^{\circ}{\rm KP}$ $\theta_3({\rm cot}) = 1 \ {}^{\circ}{\rm K$	FWD $M_f(\text{MPa}) = 3.81 \times 10^5 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$ 164 0.67 0.2 Hyannis sand  Frozen RPB $M_f(\text{MPa}) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5 RPB $M_f(\text{MPa}) = 33.45 (w_u/w_t)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_f(\text{MPa}) = 7.147 \times 10^6 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_f(\text{MPa}) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_f(\text{MPa}) = 82.27 (w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_f(\text{MPa}) = 1.56 \times 10^5 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_f(\text{MPa}) = 7.17 \times 10^6 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_f(\text{MPa}) = 1.01 \times 10^4 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_f(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_f(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ $\theta_0 = 1^{\circ}C$ $\theta_0 = 1^$				174		0.1
Hyanais sand  Frozen RPB $M_r(\text{MPa}) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5 RPB $M_r(\text{MPa}) = 33.45(w_u/w_t)^{-2.03}$ 69 0.95 0.6  Thawed FWD $M_r(\text{MPa}) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(\text{MPa}) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_r(\text{MPa}) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^3 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(\text{MPa}) = 7.17 \times 10^4 f(\psi)^{-1.349} f_1(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7  Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{-2.84}$ 118 0.63 0.2  RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{\text{oct}})/\sigma_0]$ $f_1(\psi) = [(101.38 - \psi)/\psi_o]$ $f_2(\phi) = 1 \text{ kPa}$ $f_3(\sigma) = (J_1/\sigma_o)$ $f_4(\phi) = 1 \text{ kPa}$ $f_3(\sigma) = 1 \text{ kPa}$ $f_4(\sigma) = 1  k$	Hyanais sand  Frozen RPB $M_r(\text{MPa}) = 0.68 \ f(\gamma)^{11.0} \ (w_u/w_r)^{-2.12}$ 69 0.96 0.5  RPB $M_r(\text{MPa}) = 33.45(w_u/w_r)^{-2.03}$ 69 0.95 0.6  Thawed FWD $M_r(\text{MPa}) = 7.147 \times 10^4 \ f(\psi)^{-1.782} \ f_1(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_r(\text{MPa}) = 3.57 \times 10^7 \ f(\psi)^{-3.276} \ f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_r(\text{MPa}) = 82.27(w_u/w_r)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^3 \ f(\psi)^{-1.76} \ f_1(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(\text{MPa}) = 7.17 \times 10^4 \ f(\psi)^{-1.349} \ f_1(\sigma)^{0.125}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_r)^{-3.446}$ 108 0.87 0.  Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^4 \ f(\psi)^{-2.54} \ f_1(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(\text{MPa}) = 1.29 \times 10^7 \ f(\psi)^{-2.54} \ f_1(\sigma)^{0.192}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{\text{oct}})/\sigma_{\text{ol}}]$ $f_1(\sigma) = [(10.18 - \psi)/\psi_{\text{ol}}]$ $\psi_0 = 1 \ \text{kPa}$ $f = \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f_1(\sigma) = (J_1/\sigma_{\text{ol}})$ $f_1(\sigma) = (J_1/\sigma_{\text{ol}})$ $f_1(\sigma) = 1 \ \text{mg/m}^4$		FWD	$M_r(\text{MPa}) = 3.93 \times 10^4 f(\psi)^{-2.67} f(\gamma)^{6.18} f_1(\sigma)^{0.457}$	164	0.67	0.2
Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_r)^{-2.12}$ 69 0.96 0.5 RPB $M_r(MPa) = 33.45(w_u/w_r)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 82.27(w_u/w_r)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^3 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_r)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-2.54}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.54}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $f = 0.01 \times 10^2 (w_u/w_r)^{-2.54}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $f = 0.01 \times 10^2 (w_u/w_r)^{-2.54}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $f = 0.01 \times 10^2 (w_u/w_r)^{-2.54}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $f = 0.01 \times 10^2 (w_u/w_r)^{-2.54}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $f = 0.01 \times 10^2 (w_u/w_r)^{-2.54}$ 118 0.54 0.3	Frozen RPB $M_r(MPa) = 0.68 f(\gamma)^{11.0} (w_u/w_t)^{-2.12}$ 69 0.96 0.5 RPB $M_r(MPa) = 33.45(w_u/w_t)^{-2.03}$ 69 0.95 0.6 Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^3 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-2.59} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.54}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi$ = number of points $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(10.138 - \psi)/\psi_o]$ $f_2(\sigma) = 1 \text{ kPa}$ $f_3(\sigma) = (J_1/\sigma_o)$ $f_4(\sigma) = 1 \text{ kPa}$ $f_4(\sigma) = 1  kPa$		FWD	$M_r(\text{MPa}) = 3.81 \times 10^4 f(\psi)^{-2.817} f(\gamma)^{7.43} f_1(\sigma)^{0.375}$	164	0.67	0.2
Thawed FWD $M_r(MPa) = 33.45(w_u/w_r)^{-2.03}$ 69 0.95 0.6 FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_2(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone Frozen RPB $M_r(MPa) = 82.27(w_u/w_r)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^3 f(\psi)^{-1.76} f_2(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till Frozen RPB $M_r(MPa) = 1.01 \times 10^3 (w_u/w_r)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-2.89} f_2(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform FWD = falling weight deflectometer waveform $n = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\psi) = [(101.38 - \psi)/\psi_o]$ $\psi_o = 1 \text{ kPa}$ $f_1(\sigma) = (J_1/\sigma_o)$ $w_1 = \text{total water content}$ $f_1(\gamma) = \gamma/\gamma_o$ $f_1(\sigma) = (J_1/\sigma_o)$ $f_1(\sigma) = 1 \text{ max}/m^2$	Thawed FWD $M_r(\text{MPa}) = 33.45(w_u/w_t)^{-2.03}$ 69 0.95 0.6  Thawed FWD $M_r(\text{MPa}) = 7.147 \times 10^4 f(\psi)^{-1.782} f_2(\sigma)^{0.264}$ 128 0.71 0.1  FWD $M_r(\text{MPa}) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_r(\text{MPa}) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^3 f(\psi)^{-1.76} f_2(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(\text{MPa}) = 7.17 \times 10^4 f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.  Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $n = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{\text{oct}})/\sigma_o]$ $f_2(\sigma) = (J_1/\sigma_o)$ $f_3(\sigma) = (J_1/\sigma_o)$ $f_4(\sigma) = (J_1/\sigma_o)$ $f_4(\sigma$	Hyannis sand					
Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^5 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7 Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi$ = number of points $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = 1 \text{ kPa}$ $f_1(\sigma) = 1 $	Thawed FWD $M_r(MPa) = 7.147 \times 10^4 f(\psi)^{-1.782} f_1(\sigma)^{0.264}$ 128 0.71 0.1 FWD $M_r(MPa) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1 Dense-graded stone  Frozen RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^9 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.389} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{-2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi$ = number of points $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(101.38 - \psi)/\psi_o]$ $f_1(\sigma) = (J_1/\sigma_o)$	Frozen			69	0.96	0.5
FWD $M_r(\text{MPa}) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.19  Dense-graded stone  Frozen RPB $M_r(\text{MPa}) = 82.27 (w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^5 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(\text{MPa}) = 7.17 \times 10^6 f(\psi)^{-1.389} f_1(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7  Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f(\psi) = [(101.38-\psi)/\psi_o]$ $M_r = \text{resilient modulus}$ $\sigma_o = 1 \text{ kPa}$ $\psi_o = 1 \text{ kPa}$ $f = \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f(\gamma) = \gamma/\gamma_o$ $f_1(\sigma) = (J_1/\sigma_o)$ $w_t = \text{total water content}$ $\gamma_o = 1 \text{ mg/m}^3$	FWD $M_r(\text{MPa}) = 3.57 \times 10^r f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$ 61 0.74 0.1  Dense-graded stone  Frozen RPB $M_r(\text{MPa}) = 82.27 (w_u/w_t)^{-2.03}$ 32 0.97 0.4  Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^s f(\psi)^{-1.76} f_2(\sigma)^{0.136}$ 64 0.65 0.2  RPB $M_r(\text{MPa}) = 7.17 \times 10^a f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ 64 0.65 0.2  Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^3 (w_u/w_t)^{-3.446}$ 108 0.87 0.  Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^a f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(\text{MPa}) = 1.29 \times 10^r f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $\theta_0 = 1^{\circ}\text{C}$ $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{\text{oct}})/\sigma_o]$ $f(\psi) = [(101.38-\psi)/\psi_o]$ $M_r = \text{resilient modulus}$ $\sigma_0 = 1 \text{ kPa}$ $\psi_0 = 1 \text{ kPa}$ $f =  \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f(\gamma) = \gamma/\gamma_o$ $f_1(\sigma) = (J_1/\sigma_o)$ $w_1 = \text{total water content}$ $\gamma_0 = 1 \text{ mg/m}^r$						0.6
Dense-graded stone         Frozen         RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32         0.97         0.4           Thawed         RPB $M_r(MPa) = 1.56 \times 10^s f(\psi)^{-1.76} f_2(\sigma)^{0.136}$ 64         0.65         0.2           RPB $M_r(MPa) = 7.17 \times 10^s f(\psi)^{-1.389} f_1(\sigma)^{0.1725}$ 64         0.65         0.2           Sibley till         Frozen         RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108         0.87         0.7           Thawed         RPB $M_r(MPa) = 7.47 \times 10^s f(\psi)^{2.89} f_1(\sigma)^{0.192}$ 118         0.63         0.2           RPB $M_r(MPa) = 1.29 \times 10^r f(\psi)^{-2.84}$ 118         0.63         0.2           NOTES:         RPB $m_r(MPa) = 1.29 \times 10^r f(\psi)^{-2.84}$ 118         0.54         0.3           NOTES:         RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ $\theta_0 = 1^nC$	Dense-graded stone         Frozen         RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32         0.97         0.4           Thawed         RPB $M_r(MPa) = 1.56 \times 10^5 f(\psi)^{-1.76} f_2(\sigma)^{0.136}$ 64         0.65         0.2           RPB $M_r(MPa) = 7.17 \times 10^4 f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ 64         0.65         0.2           Sibley till         Frozen         RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108         0.87         0.           Thawed         RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118         0.63         0.2           RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118         0.63         0.2           NOTES:         RPB         repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ $\theta_0 = 1^{\circ}C$ FWD = falling weight deflectometer waveform $\theta_0 = 1^{\circ}C$ $f(\psi) = [(101.38 - \psi)/\psi_0]$ $M_r = resilient modulus$ $\sigma_0 = 1 \text{ kPa}$ $\psi_0 = 1 \text{ kPa}$ $f = load$ wave frequency $w_0 = 1 \text{ kPa}$ $f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (f_1/\sigma_0)$ $f_1(\sigma) = (f_1/\sigma_0)$ $f_1(\sigma) = (f_1/\sigma_0)$	Thawed					0.13
Frozen RPB $M_r(\text{MPa}) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(\text{MPa}) = 1.56 \times 10^9 \ f(\psi)^{-1.76} \ f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(\text{MPa}) = 7.17 \times 10^6 \ f(\psi)^{-1.589} \ f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7 Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^6 \ f(\psi)^{2.829} \ f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(\text{MPa}) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_0]$ $f(\psi) = [(101.38 - \psi)/\psi_0]$ $\psi_0 = 1 \text{ kPa}$ $f = \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (J_1/\sigma_0)$ $w_t = \text{total water content}$ $\gamma_0 = 1 \text{ mg/m}^3$	Frozen RPB $M_r(MPa) = 82.27(w_u/w_t)^{-2.03}$ 32 0.97 0.4 Thawed RPB $M_r(MPa) = 1.56 \times 10^5 f(\psi)^{-1.76} f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^6 f(\psi)^{-1.589} f_1(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES: RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_0]$ $f(\psi) = [(101.38 - \psi)/\psi_0]$ $M_r = \text{resilient modulus}$ $\sigma_0 = 1 \text{ kPa}$ $\psi_0 = 1 \text{ kPa}$ $f = \log d$ wave frequency $w_u = \text{unifrozen water content}$ $f(\gamma) = \gamma/\gamma_0$ $\gamma_0 = 1 \text{ mg/m}$	n		$M_{\rm r}({\rm MPa}) = 3.57 \times 10^7 f(\psi)^{-3.276} f_1(\sigma)^{0.3628}$	61	0.74	0.19
Thawed RPB $M_r(MPa) = 1.56 \times 10^5 \ f(\psi)^{-1.76} \ f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 \ f(\psi)^{-1.589} \ f_2(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7 Thawed RPB $M_r(MPa) = 7.47 \times 10^4 \ f(\psi)^{2.829} \ f_2(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \ C$ $\pi = \text{number of points}$ $f_2(\sigma) = [(J_2/\tau_{oct})/\sigma_0] \qquad f(\psi) = [(101.38 - \psi)/\psi_0]$ $M_r = \text{resilient modulus}$ $\sigma_0 = 1 \ kPa$ $f = \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (J_1/\sigma_0) \qquad w_t = \text{total water content}$	Thawed RPB $M_r(MPa) = 1.56 \times 10^3 \ f(\psi)^{-1.76} \ f_1(\sigma)^{0.136}$ 64 0.65 0.2 RPB $M_r(MPa) = 7.17 \times 10^4 \ f(\psi)^{-1.589} \ f_2(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 \ f(\psi)^{2.829} \ f_2(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points}$ $M_r = \text{resilient modulus}$ $\sigma_0 = 1 \text{ kPa}$ $f = \text{load wave frequency}$ $w_u = \text{unfrozen water content}$ $f_1(\sigma) = (J_1/\sigma_0)$ $w_t = \text{total water content}$ $\gamma_0 = 1 \text{ mg/m}$	_		M (MPa) = 92 27/ />-2.01	13	0.07	0.4
Sibley till  Frozen RPB $M_r(\text{MPa}) = 7.17 \times 10^4 f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ Frozen RPB $M_r(\text{MPa}) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ RPB $M_r(\text{MPa}) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ RPB $M_r(\text{MPa}) = 1.29 \times 10^7 f(\psi)^{-2.84}$ NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $\pi = \text{number of points}$ $f_2(\sigma) = [(J_2/\tau_{oc})/\sigma_o]$ $f_3(\sigma) = [(J_3/\tau_{oc})/\sigma_o]$ $f_4(\sigma) = (101.38 - \psi)/\psi_o]$ $f_4(\sigma) = (J_1/\sigma_o)$	RPB $M_r(MPa) = 7.17 \times 10^a f(\psi)^{-1.589} f_2(\sigma)^{0.1725}$ 64 0.65 0.2 Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.  Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points} \qquad f_3(\sigma) = [(J_3/\tau_{oct})/\sigma_0] \qquad f(\psi) = [(101.38-\psi)/\psi_0]$ $M_r = \text{resilient modulus} \qquad \sigma_0 = 1 \text{ kPa} \qquad \psi_0 = 1 \text{ kPa}$ $f = \text{load wave frequency} \qquad w_u = \text{unfrozen water content} \qquad f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (J_1/\sigma_0) \qquad w_1 = \text{total water content} \qquad \gamma_0 = 1 \text{ mg/m}$			• • •			
Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.54}$ 118 0.63 0.2  RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.54}$ 118 0.63 0.2  NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1  ^{\circ}\text{C}$ $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_2(\sigma) = 1  ^{\circ}\text{RPB}$ $f_3(\sigma) = 1  ^{\circ}\text{RPB}$	Sibley till  Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.63 0.2  RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1  ^{\circ}\text{C}$ $\pi = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_2(\sigma) = 1  ^{\circ}\text{RPB}$ $f_3(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_4(\sigma) = (J_1/\sigma_o)$	1 HOWELL					
Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0.7  Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118 0.63 0.2  RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.44}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points} \qquad f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o] \qquad f(\psi) = [(101.38-\psi)/\psi_o]$ $M_r = \text{resilient modulus} \qquad \sigma_0 = 1 \text{ kPa} \qquad \psi_0 = 1 \text{ kPa}$ $f = \text{load wave frequency} \qquad w_u = \text{unfrozen water content} \qquad f(\gamma) = \gamma/\gamma_o$ $f_1(\sigma) = (J_1/\sigma_o) \qquad w_t = \text{total water content} \qquad \gamma_0 = 1 \text{ mg/m}^3$	Frozen RPB $M_r(MPa) = 1.01 \times 10^2 (w_u/w_t)^{-3.446}$ 108 0.87 0. Thawed RPB $M_r(MPa) = 7.47 \times 10^4 f(\psi)^{2.829} f_1(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.54}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform $T = \theta/\theta_0$ FWD = falling weight deflectometer waveform $\theta_0 = 1 \text{ °C}$ $\pi = \text{number of points} \qquad f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o] \qquad f(\psi) = [(101.38-\psi)/\psi_o]$ $M_r = \text{resilient modulus} \qquad \sigma_0 = 1 \text{ kPa} \qquad \psi_0 = 1 \text{ kPa}$ $f = \text{load wave frequency} \qquad w_u = \text{unfrozen water content} \qquad f(\gamma) = \gamma/\gamma_o$ $f_1(\sigma) = (J_1/\sigma_o) \qquad w_t = \text{total water content} \qquad \gamma_0 = 1 \text{ mg/m}^3$	Siblev till	N. D	MATERIAL OF THE STORY OF STREET	<b>U</b>	0.05	0.2
Thawed RPB $M_r(MPa) = 7.47 \times 10^4 \ f(\psi)^{2.829} \ f_2(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(MPa) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $n = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{ocl})/\sigma_o]$ $f_2(\sigma) = 1 \ \text{kPa}$ $f_3(\sigma) = 1 \ \text{kPa}$ $f_4(\sigma) = (J_1/\sigma_o)$	Thawed RPB $M_r(\text{MPa}) = 7.47 \times 10^{6} f(\psi)^{2.829} f_2(\sigma)^{0.192}$ 118 0.63 0.2 RPB $M_r(\text{MPa}) = 1.29 \times 10^{7} f(\psi)^{-2.84}$ 118 0.54 0.3 NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $n = \text{number of points}$ $f_1(\sigma) = [(J_1/\tau_{ocl})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{ocl})/\sigma_o]$ $f_2(\sigma) = 1 \text{ kPa}$ $f_3(\sigma) = 1 \text{ kPa}$ $f_4(\sigma) = (J_1/\sigma_o)$	•	RPB	$M_r(\text{MPa}) = 1.01 \times 10^2 (w_{\cdot \cdot}/w_{\cdot})^{-3.446}$	108	0.87	0.1
NOTES:  RPB $M_{\rm r}({\rm MPa}) = 1.29 \times 10^7 \ f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $n = {\rm number\ of\ points}$ $f_i(\sigma) = [(J_i/\tau_{\rm oct})/\sigma_o]$ $f_i(\sigma) = [(J_i/\tau_{\rm oct})/\sigma_o]$ $f_i(\phi) = [(101.38-\psi)/\psi_o]$ $f_i(\sigma) = 1 \ {\rm kPa}$ $f_i(\sigma) = (J_i/\sigma_o)$	NOTES:  RPB $M_r(MPa) = 1.29 \times 10^7 f(\psi)^{-2.84}$ 118 0.54 0.3  NOTES:  RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $n = number of points$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_1(\sigma) = [(J_1/\tau_{oct})/\sigma_o]$ $f_2(\sigma) = 1 \text{ kPa}$ $f_3(\sigma) = 1 \text{ kPa}$ $f_4(\sigma) = 1 \text{ kPa}$ $f_4(\sigma) = (J_1/\sigma_o)$						0.2
RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $\sigma = 1 \text{ C}$	RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $\sigma = 0$ = 1 °C $\sigma = 0$ = 1 kPa $\sigma_0 = 1 k$ Pa		RPB		118	0.54	0.3
RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $ \theta_0 = 1  ^{\circ}C $	RPB = repeated-plate bearing apparatus waveform  FWD = falling weight deflectometer waveform $\sigma_0 = 1 \text{ C}$ $\sigma_0 = 1 \text{ C}$ $\sigma_0 = 1 \text{ N}$ $\sigma_0 = 1 \text{ kPa}$	NOTES:					
FWD = falling weight deflectometer waveform $ \eta = \text{number of points} \qquad f_1(\sigma) = \left[ (J_1/\tau_{\text{oct}})/\sigma_0 \right] \qquad f(\psi) = \left[ (101.38 - \psi)/\psi_0 \right] \\ M_r = \text{resilient modulus} \qquad \sigma_0 = 1 \text{ kPa} \qquad \psi_0 = 1 \text{ kPa} \\ f = \text{load wave frequency} \qquad w_u = \text{unfrozen water content} \qquad f(\gamma) = \gamma/\gamma_0 \\ f_1(\sigma) = (J_1/\sigma_0) \qquad w_t = \text{total water content} \qquad \gamma_0 = 1 \text{ mg/m} $	FWD = falling weight deflectometer waveform $ \eta = \text{number of points} \qquad f_1(\sigma) = \left[ (J_1/\tau_{\text{oct}})/\sigma_0 \right] \qquad f(\psi) = \left[ (101.38 - \psi)/\psi_0 \right] \\ M_r = \text{resilient modulus} \qquad \sigma_0 = 1 \text{ kPa} \qquad \psi_0 = 1 \text{ kPa} \\ f = \text{load wave frequency} \qquad w_u = \text{unfrozen water content} \qquad f(\gamma) = \gamma/\gamma_0 \\ f_1(\sigma) = (J_1/\sigma_0) \qquad w_t = \text{total water content} \qquad \gamma_0 = 1 \text{ mg/m} $		olate bearing ap	oparatus waveform	$T = \theta/\theta_0$		
$M_r$ = resilient modulus $\sigma_o = 1 \text{ kPa}$ $\psi_o = 1 \text{ kPa}$ $f = load$ wave frequency $w_u = unfrozen$ water content $f(\gamma) = \gamma/\gamma_o$ $f_i(\sigma) = (J_i/\sigma_o)$ $w_i = total$ water content $\gamma_o = 1 \text{ mg/m}$	$M_r$ = resilient modulus $\sigma_o = 1 \text{ kPa}$ $\psi_o = 1 \text{ kPa}$ $f = load$ wave frequency $w_u = unfrozen$ water content $f(\gamma) = \gamma/\gamma_o$ $f_i(\sigma) = (J_i/\sigma_o)$ $w_i = total$ water content $\gamma_o = 1 \text{ mg/m}$		_		-		
$f = load$ wave frequency $w_u = unfrozen$ water content $f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (J_1/\sigma_0)$ $w_t = total$ water content $\gamma_0 = 1 \text{ mg/m}^3$	$f = load$ wave frequency $w_u = unfrozen$ water content $f(\gamma) = \gamma/\gamma_0$ $f_1(\sigma) = (J_1/\sigma_0)$ $w_t = total$ water content $\gamma_0 = 1 \text{ mg/m}$					/ <b>∤</b> J	
$f_1(\sigma) = (J_1/\sigma_0)$ $w_1 = \text{total water content}$ $\gamma_0 = 1 \text{ mg/m}^3$	$f_i(\sigma) = (J_i/\sigma_0)$ $w_i = \text{total water content}$ $\gamma_0 = 1 \text{ mg/m}^3$				-		
5	5		- •	=			
5	5						
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Figure 4. Resilient modulus of asphalt concrete vs temperature for various loading conditions.

tice for characterizing the nonlinear resilient modulus of granular soil. It was found, however, in tests on thawed test soil that  $M_{\rm r}$  not only increased with  $J_1$  but also tended to decrease somewhat with increasing principal stress ratio, an effect that was particularly evident when the minor principal stress  $\sigma_3$  was held constant and the deviator stress  $\sigma_{\rm d} = \sigma_1 - \sigma_3$  was increased to a higher level. Another stress function,  $J_2/\tau_{\rm oct}$ , was selected to reflect the two different trends of variation of  $M_{\rm r}$  with stress. The second stress invariant can be expressed as

$$J_2 = \sigma_1 \sigma_2 + \sigma_2 \sigma_3 + \sigma_3 \sigma_1$$

but in triaxial tests with  $\sigma_2 = \sigma_3$  and  $\sigma_d = \sigma_1 - \sigma_3$ , it follows that

$$J_2 = 3\sigma_3^2 + 2\sigma_3\sigma_d.$$

Similarly, the general form of the expression for the octahedral shear stress is

$$\tau_{\text{oct}} = \frac{1}{3} [(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2}$$

but in triaxial tests it is found that

$$\tau_{\rm oct} = \sqrt{\frac{2}{3}} \ \sigma_{\rm d}$$

and the selected invariant stress parameter can be expressed as

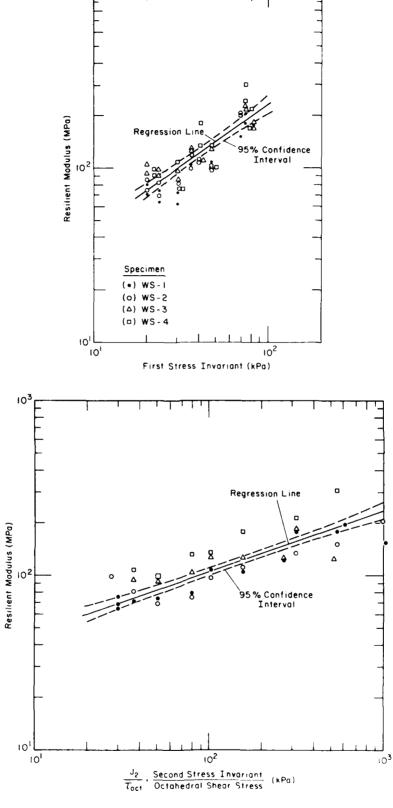
$$J_2/\tau_{\rm oct} = \frac{9\sigma_3^2 + 6\sigma_3\sigma_{\rm d}}{\sqrt{2}\,\sigma_{\rm d}}$$

Because the data sets from the RPB and FWD load pulses indicated no statistically significant difference (Cole et al. 1981), the results were merged. The equations resulting from regression analyses are expressed in terms of the two selected invariant stress parameters (Table 1). It is noteworthy that the coefficient of determination  $(R^2)$ 

Table 2. Applied stress levels.

Static axial	Static confining	Cyclic axial*	
stress, o <sub>1</sub>	stress, o3	stress, od	
(kPa)	(kPa)	(kPa)	$\sigma_1/\sigma_3$
	a. Frozen spec	imens	
_	69	60	_
_	69	138	_
_	69	207	_
_	69	276	_ _ _
_	69	345	_
_	69	482	_
_	69	620	
_	69	827	_
<b>b.</b> 7	Thawed and recover	ed specimens	
_	6.9	3.4	1.5
	13.8	6.9	1.5
_ _ _	27.6	13.8	1.5
_	48.3	24.1	1.5
_	69.0	34.5	1.5
_	6.9	6.9	2.0
_	13.8	13.8	2.0
_	27.6	27.6	2.0
_	48.3	48.3	2.0
_	69.0	69.0	2.0
_	6.9	10.3	2.5
_	13.8	20.7	2.5
_	27.6	41.4	2.5
_	48.3	72.4	2.5
	69.0	103.4	2.5
	c. Natural subgrade	material	
13.8	5.5	3.4	_
27.6	11.0	6.9	_
55.2	22.1	13.8	_

Deviator stress.



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Figure 5. Resilient modulus vs invariant stress parameters for natural subgrade.

is somewhat higher for the equation in terms of  $J_2/\tau_{\rm oct}$ . The test data and regression lines are shown in Figure 5, with a 95% confidence interval

#### Test soils

Each of the six test soils was subjected to repeated-load triaxial tests in the frozen, thawed, recovering, and recovered conditions. The term thawed can be used in two senses. Broadly construed, it means any soil that has been frozen and now exists at a temperature above 0°C. While the thaw front (0°C isotherm) is advancing into the ground or through a specimen, the soil is said to be thawing. With passage of the 0°C isotherm the soil just thawed begins to recover, a time-dependent process that starts with dissipation of pore pressure and consolidation and, for soils above the water table, progresses through a desaturation phase with build-up of moisture tension. The term "thawed" is used in this report to describe soil still undergoing the recovery process, but the term "recovering" is also used to refer to the period of consolidation and build-up of moisture tension. Recovery culminates in an equilibrium in which the state of stress in the pore water is affected only by external influences such as weather or the position of the ground water table. The term "recovered" is applied to the latter equilibrium condition, generally reached in the fall shortly before onset of another freezing cycle.

The triaxial tests were performed on a closed-loop electrohydraulic testing machine. Cores 50.8 or 57.2 mm in diameter, as noted above, were trimmed to a length of 127.0 mm (for the Hyannis, Ikalanian, Hart Brothers, and Graves sands) and tested in a triaxial cell. Remolded samples 152.4 mm in diameter were made from the Sibley till and dense-graded stone to test in a larger triaxial cell. The testing regime in all cases was to apply and maintain a constant confining pressure  $\sigma_3$  and to apply repeatedly a deviator stress  $\sigma_d$ . The deviator stress pulse, either 1 sec on and 2 sec off (RPB pulse), or 28 ms on and 2 sec off (FWD pulse), was repeated 200 times at each stress level.

Specimen temperatures for tests in the frozen condition ranged from -0.2 to -10.0 °C. Confining pressure was 69.0 kPa and deviator stresses ranged from 69 to 827 kPa. Once tested in the frozen state, each specimen was thawed in the triaxial device and retested repeatedly to characterize the thawed and recovering conditions. In each test the specimen was allowed to drain or come to equilibrium under the applied confining stress before the

cyclic deviator stress was applied. After the first test in the thawed condition, gradual recovery was simulated by inducing successive step increases in moisture tension  $\psi$ , performing triaxial tests at each  $\psi$  level at a range in values of  $\sigma_3$  and  $\sigma_d$  (Table 2). For this purpose the top cap of the specimen was removed and the specimen was air-dried to attain a somewhat higher level of moisture tension  $\psi$ . This procedure was repeated until the thawed specimen had been tested at three or more levels of  $\psi$ .

The results of multiple linear regression analysis of the data on the six test soils in the frozen, thawed (recovering), and in some cases the recovered conditions are given in Table 1. In the frozen state the significant variables are temperature, deviator stress, and in some cases total moisture content. Preferring invariant stress function for application to the field in-situ problem, we have expressed the stress function in terms of octahedral shear stress. For Hart Brothers sand, Hyannis sand, Sibley till, and dense-graded stone the validity of the equations was extended to the melting point (Cole 1984), and the moduli are expressed as a function of the unfrozen water contents.

In the thawed and recovering states the significant variables are a moisture tension parameter  $f(\psi)$ , which is atmospheric pressure minus the gauge value of soil moisture tension  $(u_a-\psi)$ , dry density  $\gamma_d$ , and a stress parameter, either  $J_1$  or  $J_2$ /  $\tau_{\rm oct}$ . In some cases the use of  $J_2/\tau_{\rm oct}$  gave substantially higher values of  $R^2$ . It was intended that the field loading tests be analyzed using the expressions for resilient moduli in terms of  $J_2/\tau_{oct}$  for all the soils, because this model correlated better in some cases with the laboratory data. However, due to an early problem with NELAPAV, the elastic layered analysis program developed for deflection basin analyses, the first analyses of field data were performed using nonlinear moduli expressed in terms of  $J_1$ . When the problem with NELAPAV was corrected, the deflection basins of the remaining test sections were analyzed using regression equations expressed in terms of  $J_2/\tau_{oct}$ . Typical plots representing the dependency of the resilient modulus of thawed soil on either of the two invariant stress functions are given in Figure 6.

Samples of the test soils taken in the fall of 1978 were construed to reflect the fully recovered conditions; they were tested at the same stress levels as the thawed/recovering specimens but at only the level of  $\psi$  prevailing in-situ when the samples were taken. Regression analyses of the results (Table 1) showed that the stress parameter,  $J_1$  or  $J_2/\tau_{\rm oct}$ , is a

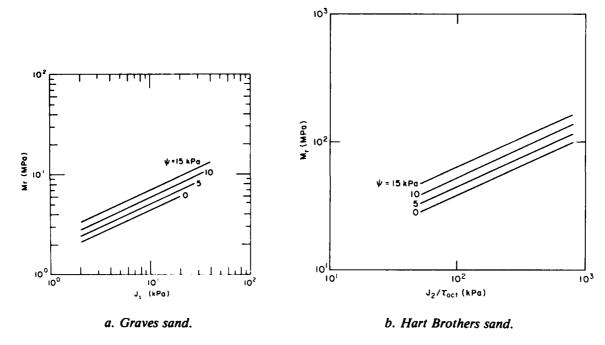


Figure 6. Resilient modulus vs invariant stress parameters for two thawed test soils.

significant variable. In some cases  $\psi$  was accepted as a variable, while in other cases the range of  $\psi$  in the available data was small and did not meet the test for acceptance as statistically significant.

#### **FIELD TESTS**

Laboratory repeated-load triaxial testing of thawed soils requires special techniques that were under development as an objective of this project. Consequently it was essential to test the procedures and verify the moduli determined through their use. The method chosen to validate the procedures was to calculate surface deflection basins in experimental pavements with the aid of the laboratory-determined moduli and to compare these calculated basins with surface deflection basins observed during plate-loading tests on the same experimental pavements. To this end, the research included RPB and FWD tests on the six paved soil test sections selected from the 24 test sections at Winchendon, Massachusetts.

But the validation of moduli determined by laboratory tests was only one of the two principal objectives of the field testing. Laboratory testing alone does not provide the time-dependent evaluation of the resilient modulus of the various layers of the pavement structure that is needed for pavement evaluation and design. The stresses needed for evaluating the resilient modulus can be calculated in relation to the particular traffic loading for which the pavement analysis is being made, but in-situ seasonal variation of temperature and moisture tension must also be assessed to permit determination of resilient moduli through a complete annual cycle. Subsurface temperatures, frost depths, and moisture tension are among the parameters that can be predicted by means of the mathematical model of frost heave being developed under another phase of this research project (Guymon et al., in prep.). Alternatively, temperatures and moisture tensions can be monitored insitu throughout the year to provide the needed link for laboratory assessment of time-dependent seasonal variation of resilient modulus. This was the second objective of the field work at Winchendon.

Subsurface temperatures were monitored throughout the year at each of the six test sections at Winchendon, by means of thermocouples installed at various depths. Soil moisture tensiometers (McKim et al. 1976) also were installed at various depths in each test section and were read each time a plate-bearing test was performed.

Field in-situ plate-bearing tests using pulsed loading were performed to verify the laboratory-determined moduli and as a means of evaluating seasonal variations in the moduli. Two types of insitu tests were performed on the six Winchendon

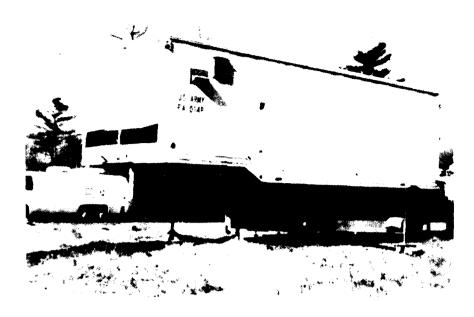


Figure 7. RPB test van with reference beam for LVDTs.

test sections. The first type was the repeated-load plate-bearing test (RPB). The equipment is mounted in the center of a large enclosed semi-trailer (Fig. 7), which is ballasted and reinforced to provide a firm reaction for the plate load. The load was applied by an air actuator, and loads up to about 53 kN can be applied at frequencies up to about 20/min. A load ell located on top of the plate senses each load repetition, which is recorded on strip charts. The recorder also traces the outputs of linear variable differential transform-

ers (LVDTs) supported by a reference beam and placed in contact with the pavement surface at various radial distances from the loading plate to measure resilient deflections. The loads were applied through a 304-mm-diameter plate, and were repeated 50 to 1000 times. The pulse duration was about 1 sec and the cycle time was about 3 sec.

The second type of in-situ test equipment used was a falling weight deflectometer (FWD) (Koole 1979). In the device we used (Fig. 8), a mass of 150 kg falls freely and strikes a shock-absorbing device

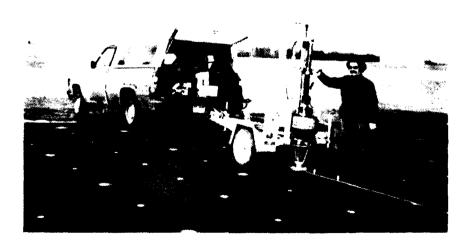
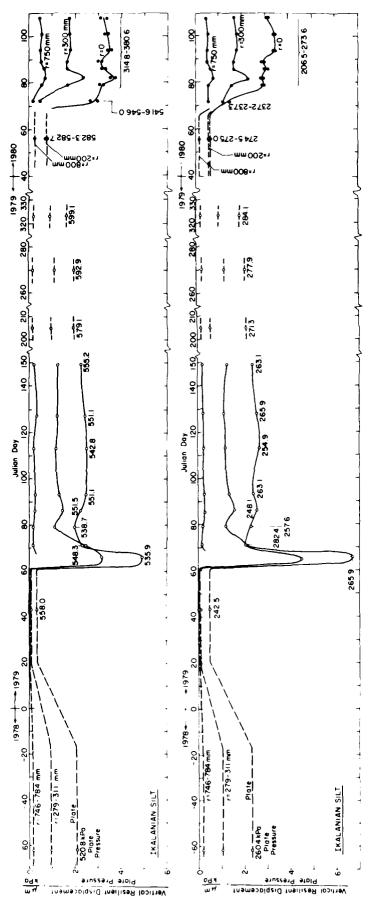


Figure 8. FWD in use at Albany County Airport, Albany, N.Y.



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Figure 9. Vertical resilient displacement at two load levels and three radii, Ikalanian sand test section.

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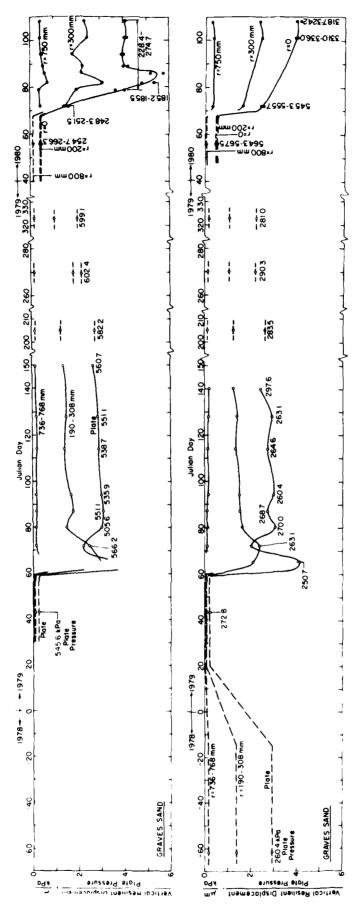


Figure 10. Vertical resilient displacement at two load levels and three radii, Graves sand test section.

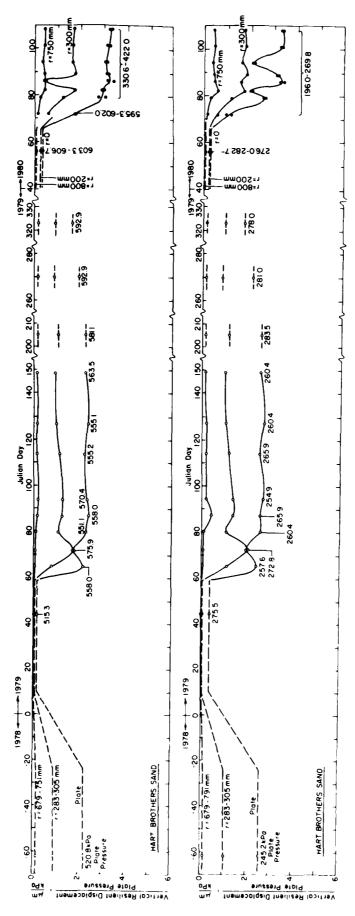
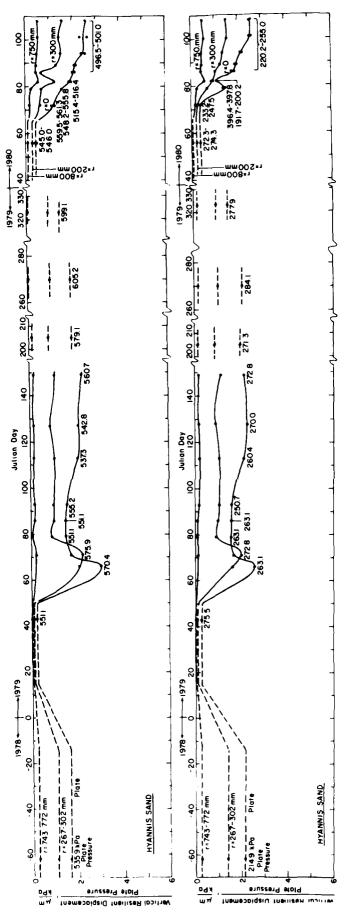


Figure 11. Vertical resilient displacement at two load levels and three radii, Hart Brothers sand test section.

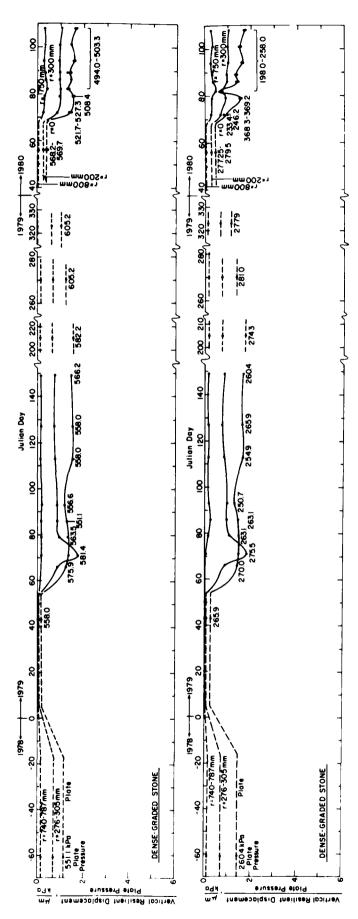
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Figure 12. Vertical resilient displacement at two load levels and three radii, Hyannis sand test section.

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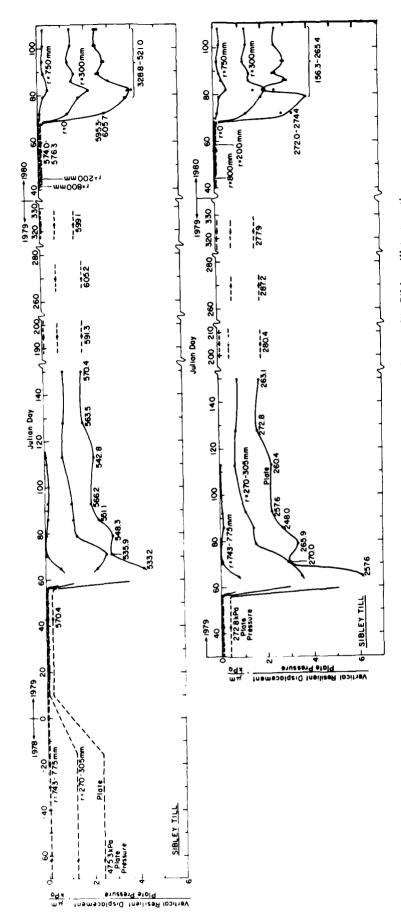
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Figure 13. Vertical resilient displacement at two load levels and three radii, dense-graded stone test section.

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Figure 14. Vertical resilient displacement at two load levels and three radii, Sibley till test section.

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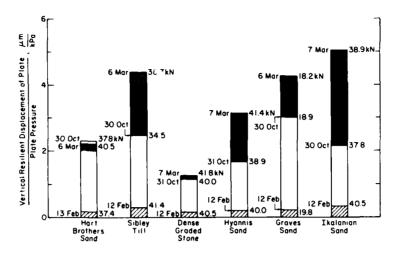


Figure 15. Vertical resilient displacement observed on six test sections prior to freezing, while frozen, and during thawing.

that imparts a 28-ms pulse load to a 300-mm-diameter plate resting on the pavement surface. Three velocity transducers (geophones) are positioned in contact with the pavement, at the center of the plate (through a small aperture in the plate) and at two radial distances from the center. Associated instrumentation integrates the velocity signal and reads out vertical displacement of the pavement in micrometers. The load imparted to the pavement is monitored by a load cell, and the output is calibrated to give plate pressure in kilopascals. For the investigation of the resilient modulus of nonlinear soils, we employed two drop heights giving pressures from 200 to 800 kPa and total loads from about 15 to 50 kN. We made five drops at each height, and repeated each test sequence a second time after repositioning the geophones to obtain deflection measurements at a total of five radii.

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The RPB tests were performed on the six test sections at two load levels on 13 occasions between October 1978 and September 1979, encompassing dates on which the test soils were frozen, partially thawed, fully thawed, recovering, and fully recovered. The FWD tests were performed on the same six test sections at two load levels on nine occasions between February and April 1980 with soils in the frozen, thawed, and recovering conditions. On each occasion pavement and test soil temperatures as well as moisture tension levels were determined. All the field test data are summarized in

Appendix A. The ground temperatures prevailing during each RPB and FWD test are shown graphically in Appendix B.

The vertical resilient displacements under plate loads observed first in the fall of 1978 decreased to small measurements in the second series of tests in February 1979, when the test soils were frozen. As the plate pressure differed somewhat in the various tests, the displacements shown in Figures 9 to 14 are normalized by dividing by the plate pressure. The plots show the sharp increase in displacement that is observed in the first test after thawing starts. The increase in surface deflection upon thawing is particularly great for the four test soils that contain the greatest fractions of fines (material passing the No. 200 sieve): the Ikalanian, Graves, and Hyannis sands and the Sibley till. Even in these soils a substantial decrease in deflection (recovery) was observed within 10 to 20 days after thawing started. In the Hart Brothers sand and the dense-graded stone the increased deflection upon thawing did not differ greatly from the fall (recovered) deflection. The comparative response of the six soils to thawing is illustrated in Figure 15.

#### **ANALYSIS OF FIELD-LOADING TESTS**

The principal objective in selecting or developing a method for analysis of the deflection basins was to be able to calculate the deflection basin resulting from application of a known load to a pavement system of a known thickness of the layers, each having linear or nonlinear resilient modulus and Poisson's ratio determined in advance by laboratory testing (forward approach). Comparison of the calculated deflection basin with the basin actually observed in field tests would permit validation of the laboratory testing procedures. Achieving a degree of success in meeting this objective led to identification of a secondary objective: to calculate the linear or nonlinear moduli corresponding to a known deflection basin (backward approach).

To meet the dual objectives, the two alternatives of the finite-element analysis and the elastic layered system analysis were considered. The finiteelement analysis has the important advantage that the modulus within each layer can vary in the radial direction for compatibility with the variation in stress. Because the entire stress regime beneath the pavement must be defined, however, computational costs would be high for a system with a sufficiently large number of elements, and doubtless prohibitively high for use with the backward approach. Consequently we selected the elastic layered system analysis. The CHEVRON computer code, including the recently developed COFE subroutine, was modified by L.H. Irwin (Irwin and Johnson 1981) to incorporate a "front end" that, for each nonlinear layer, begins with an assumed modulus, calculates the stress in the layer, uses the laboratory-developed model of stress dependency to calculate a modulus, and thereafter iterates until compatible moduli and stresses are calculated. The program, termed NELAPAV (nonlinear elastic layer analysis for pavements) then calculates stresses, strains, and deflections in the same manner as CHEVRON. An innovative feature of NELAPAV is its ability to reduce the problem of inability to account for the change in elastic modulus within a layer as the distance from the axis of the load increases. This is accomplished by recomputing the set of stress-compatible moduli for each combination of radius and depth that defines a point of interest at which stresses, strains, and deflections are to be computed. While the modulus cannot vary radially for the calculations of responses at any individual point, different stress-compatible moduli are used for calculations at other radii. The hypothesis presumes that the moduli of the materials closest to the point of interest have the greatest influence on the state of stress at that point. In this way NELAPAV accounts to some extent for the horizontal variations in moduli.

NELAPAV has been structured to incorporate five basic models of stress dependency. The program user may select one of these models for each pavement layer. The models include:

Type 1: 
$$M_r = constant$$

Type 2: 
$$M_r = K_1 J_1^{K_2}$$

Type 3: 
$$M_r = K_2 + (K_1 - \sigma_d)K_3$$
,  $\sigma_d < K_1$ 

$$M_{\rm r} = K_2 + (\sigma_{\rm d} - K_1)K_4, \ \sigma_{\rm d} > K_1$$

Type 4: 
$$M_r = K_1 (J_2/\tau_{oct})^{K_2}$$

Type 5: 
$$M_r = K_1(\tau_{oct})^{K_2}$$

where  $M_1$ ,  $J_1$ ,  $\sigma_d$ ,  $J_2$ , and  $\tau_{oct}$  are as defined earlier, and  $K_1$ ,  $K_2$ ,  $K_3$ , and  $K_4$  are regression constants.

In forward analyses of the six test sections, we have used the type 1 model for the asphalt concrete, types 1, 4, and 5 for the frozen test soils, and types 2 and 4 for the thawed and recovered test soils and the natural subgrade test soil. As the analyses proceeded, the type 4 model came to be preferred over the type 2 model for thawed soils. It was considered that the type 4 model has potential for extensive application to nonlinear soils because it incorporates a shear stress parameter and also (possibly for that reason) the laboratory characterization equations of that form yielded higher values of  $R^2$ . In recent years many investigators have concluded that the conventional model of resilient modulus as a function of  $J_1$ , represented by type 2, has serious limitations and that nonlinear models for granular materials need to account for the effect of shear strain (e.g. Brown and Pappin 1981, May and Witczak 1981). The type 4 model has the potential of accounting (indirectly) for shear stresses and strains through the inclusion of  $\tau_{\rm oct}$ , while still keeping the model very simple and avoiding computational complexities.

In addition to selecting a model for resilient modulus and inputting the applicable values for the regression constants, appropriate values for the resilient Poisson's ratio are needed. In most cases the results of the analysis are not highly sensitive to moderate changes in Poisson's ratio, which may be evaluated by tests on each material or by assigning values consistent with published test data on similar materials. Tests on the various

materials from the Winchendon test sections included measurement of axial and radial resilient strains. Poor correlation with other parameters that were monitored makes interpretation of the data uncertain (Cole et al. 1986). Accordingly, values of Poisson's ratio were selected from experience with other materials and from published test data (Table 3).

Each of the 22 RPB and FWD tests conducted at each of the six test sections has been analyzed

Table 3. Values of Poisson's ratio used in analysis.

Asphalt concrete	<i>T</i> < -2℃	0.30
	-2 < T < +1	0.35
	+1 < T < +8	0.40
	+8 < T < +16	0.45
	T > +16	0.50
Test soils Frozen		
Thawed	$\psi$ < 2 (to 4) kPa	0.30-0.35
	2 (to 4) $< \psi < 8$ (to 10)	0.45
	$\psi$ < 8 (to 10)	0.40
		0.35
Subgrade		0.35

by the forward approach. The temperatures and/ or moisture tensions prevailing in the test sections at the time of each test, together with the platebearing pressures measured for each test and moisture contents and dry densities when applicable, were taken as given values, and the stress dependency model appropriate to each layer was selected. Initial assumed values of moduli for the nonlinear layers were selected. NELAPAV calculated stresses, strains, displacements, and stresscompatible moduli throughout the system.

The comparisons between the calculated and measured deflections for the higher of the two plate loads are summarized in Figures 16-21; the comparison is similar for the lower loads (Appendix C). Deflection measurements were made at five different radii. Each of these measurements is plotted and compared with the corresponding deflection computed by NELAPAV on the basis of the conditions of the pavement system prevailing on each particular date.

Several general trends are apparent in these plots. The maximum deflections, at the center of the basin, calculated by NELAPAV tend to agree well with the maximum surface deflections measured in both the RPB and FWD tests. Proceeding outward from the plate, the different test sections

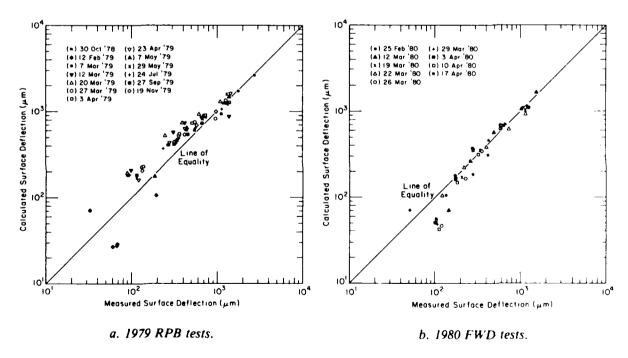
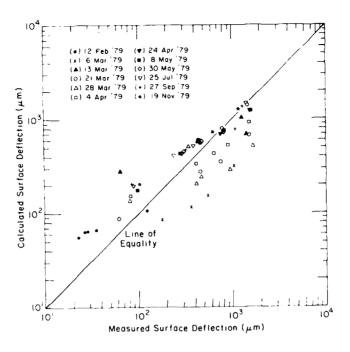
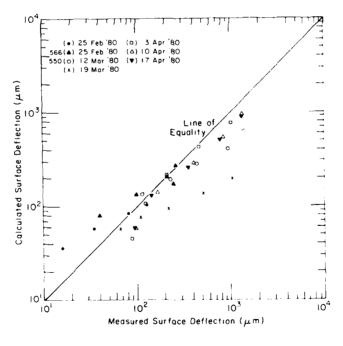


Figure 16. Measured surface deflections compared with deflections calculated by NELAPAV, Ikalanian sand test section.



a. 1979 RPB tests.



b. 1980 FWD tests.

Figure 17. Measured surface deflections compared with deflections calculated by NELAPAV, Graves sand test section.

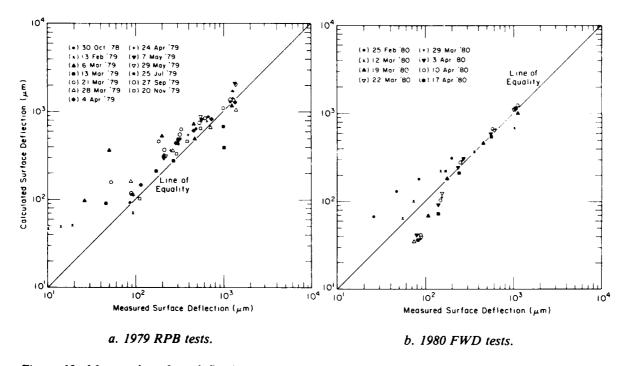


Figure 18. Measured surface deflections compared with deflections calculated by NELAPAV, Hart Brothers sand test section.

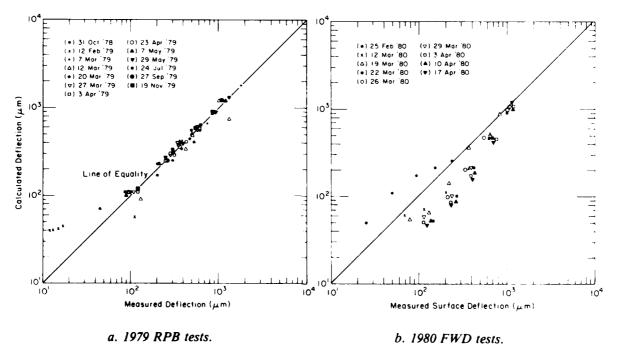


Figure 19. Measured surface deflections compared with deflections calculated by NELAPAV, Hyannis sand test section.

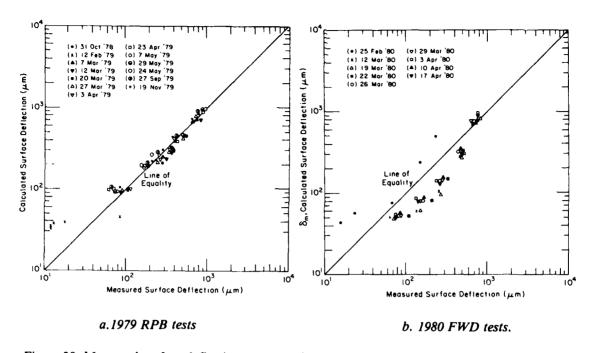


Figure 20. Measured surface deflections compared with deflections calculated by NELAPAV, densegraded stone test section.

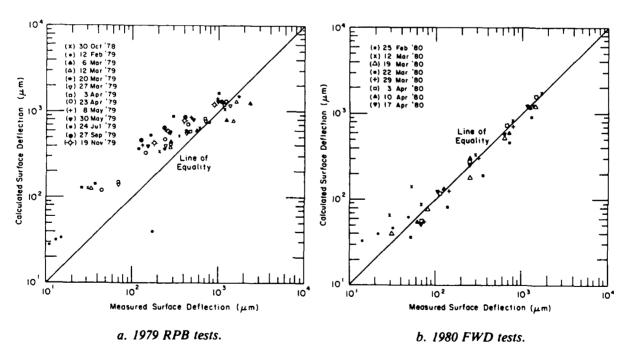


Figure 21. Measured surface deflections compared with deflections calculated by NELAPAV, Sibley till test section.

show varying degrees of agreement between the calculated and measured basins as the outer radii are considered. The Hyannis sand and densegraded stone test sections both show very good agreement all the way to the tails of the basins in the RPB tests, differing only for tests in the frozen condition. In the other test sections the RPB basins generally have calculated displacements that are higher than the measured displacements. This could be because the supports for the reference beam for measuring of deflections in the RPB test may in some cases be within the deflection basin. Thus, a possible explanation for these results is that the real deflections in the RPB tests may have been greater than those recorded. Excellent agreement is found between the calculated deflections and the deflections measured in FWD tests on Ikalanian sand, Hart Brothers sand, and Sibley till, while somewhat more scatter is evident in the plots for the other test sections.

Perhaps the most significant observation is the reasonably good agreement of the postthaw basins in general. The calculated and measured deflections differ more on those dates when the cross section included layers of frozen soil. This problem can be attributed in part to uncertainties in the definition of the exact thickness of the frozen lavers. Such uncertainty, in turn, may derive in part from interpolation of ground temperatures within the vertical string of sensors and in part from the assumption that the transition from frozen to thawed conditions occurs precisely at 0°C. For those dates with a frozen layer, the calculated deflections are generally greater than the measured deflections. An example of a thawed basin exhibiting good agreement is shown in Figure 22. Figure 23 shows the poor agreement of a basin that contained a frozen layer.

The calculated resilient moduli and other results from the analysis of the six test sections are sum-

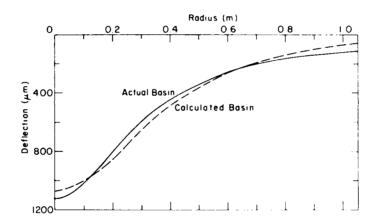


Figure 22. Calculated and actual deflection basins for 10 April 1980, Ikalanian sand: Drop height 100 mm and plate pressure 331.6 kPa.

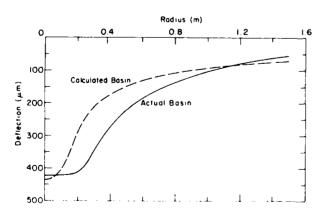


Figure 23. Calculated and actual deflection basins for 25 February 1980, Ikalanian sand: Drop height 219 mm and plate pressure 582.2 kPa.

marized in Appendix D. The resilient moduli of the test soils calculated by NELAPAV show the expected seasonal variation, with extremely high values in the frozen condition, decreasing dramatically upon thawing, and increasing somewhat during the late spring, summer, and fall. A sampling of the seasonal variation in modulus is given in Table 4, representing the upper 250-325 mm of the Ikalanian sand. The increase of the modulus from spring to fall is not as great as has been observed in earlier research on a finer grained soil (Johnson et al. 1978). The relatively modest increase during the recovery phase is believed to be attributable to the high water table at the Winchendon site, which severely restricts the build-up

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of moisture tension in the test soils. Another sampling of the variation in modulus is given in Table 5, representing the upper 250 mm of the dense-graded stone. In the case of this coarse-grained crushed stone, while the modulus is extremely high in the frozen condition, it decreases upon thawing to approximately the same level that prevails in the fall. That is to say, this material is found to be not susceptible to thaw weakening. Similar tabulations for the other test soils are given in Tables 6-11 is apparent that the test dates early in the thawing period did not coincide exactly with the brief period when the modulus of the upper layer is at its minimum level. An interpretation of the variation in modulus of the upper layer of each

Table 4. Calculated resilient modulus (MPa) in upper layer of Ikalanian sand beneath center of plate.

	Top 250	mm, 1979		Top 325	mm, 1980
	250–280 kPa Plate pressure	530-590 kPa Plate pressure		210–275 kPa Plate pressure	320–585 kPa Plate pressure
30 October 1978	77.7	105.3	25 February 1980		
12 February 1979	8257.9	5996.0	thawed, top 100 mm	32.7	49.9
7 March 1979	12.2	17.3	frozen, next 225 mm	1956.7	1432.9
12 March 1979	33.8	46.4	12 March 1980	42.0	43.3
20 March 1979	42.2	59.1	19 March 1980	30.9	35.5
27 March 1979	38.5	55.7	22 March 1980	35.1	40.9
3 April 1979	41.4	57.4	26 March 1980	32.7	38.3
23 April 1979	49.3	69.9	29 March 1980	31.2	35.4
7 May 1979	54.0	75.3	3 April 1980	26.3	31.5
29 May 1979	55.8	78.8	10 April 1980	31.3	36.5
24 July 1979	91.6	126.1	17 April 1980	31.9	36.6
27 September 1979	84.0	118.0	•		
19 November 1979	77.3	107.2			

Table 5. Calculated resilient modulus (MPa) in upper layer of dense-graded stone beneath center of plate.

	Top 250 mm, 1979			Top 250	mm, 1980
	249-276 kPa Plate pressure	547-597 kPa Plate pressure		201-278 kPa Plate pressure	451-569 kPa Plate pressure
31 October 1978	100.8	107.3	25 February 1980	101.6	110.9
12 February 1979	32,664.0	32,664.0	12 March 1980	89.5	97.4
7 March 1979	89.0	95.8	19 March 1980	93.4	96.7
12 March 1979	89.1	95.9	22 March 1980	87.6	95.4
20 March 1979	<b>87.9</b>	94.7	26 March 1980	90.6	96.1
27 March 1979	91.5	94.4	29 March 1980	91.4	96.3
3 April 1979	98.0	104.5	3 April 1980	90.0	94.9
23 April 1979	90.8	96.9	10 April 1980	98.5	104.3
7 May 1979	95.5	101.5	17 April 1980	91.0	95.8
29 May 1979	90.6	96.7	-		
24 July 1979	97.5	104.2			
27 September 1979	97.6	103.9			
19 November 1979	99.9	106.6			

Table 6. Calculated resilient modulus (MPa) in upper layer of Graves sand beneath center of plate.

	Top 350	mm, 1980
	159-267 kPa Plate pressure	240–566 kPa Plate pressure
25 February 1980	1489.0	917.4
12 March 1980		
thawed, top 100 m	66.5	96.7
frozen, next 250 mm	1723.3	962.4
19 March 1980		
thawed, top 124 mm	90.6	_
frozen, next 326 mm	1389.4	_
22 March 1980	31.0	_
26 March 1980	42.9	_
29 March 1980	37.1	44.0
3 April 1980	43.0	47.2
10 April 1980	41.7	47.8
17 April 1980	47.8	54.4

test soil, under the lower of the two test loads, is given in Figure 24.

Only very limited application of the backward approach has been made (Irwin and Johnson 1981). Its special utility is the calculation of resilient moduli for a pavement's supporting layers on which no laboratory characterization tests have been performed. Since laboratory characterizations are available for all the test soils, the backward approach has only been tested to evaluate its

effectiveness. In the calculations, the resilient modulus of the natural subgrade was assumed to be known and was assigned a value previously calculated by NELAPAV from a forward analysis based upon the laboratory nonlinear material characterization. This value was assigned merely for convenience, and in reality it is unnecessary to use NELAPAV, which calculates the stresses generated by both overburden materials and the plate load. At such relatively great depth the effect of the plate load is slight, and an approximation of the modulus based upon a simple estimate of overburden pressure would suffice.

After assigning a modulus value for the natural subgrade, the procedure is to start at the outermost radial point at which deflections were measured, assign reasonable moduli to the upper layers, and determine the modulus of the lower layer of the test soil by trials with NELAPAV to give deflections at that radius matching the measured deflections. This latter modulus, and the subgrade modulus, are carried inward to the center of the plate (r = 0), together with reasonable moduli for the upper layers of test soil, so that the asphalt concrete modulus can be determined by trials with NELAPAV to give deflections at r = 0 matching the measured deflections. The assumed values of the moduli of the upper layers of test soil are then adjusted by successive trials with NELAPAV to give a better fit with the measured deflections at the intermediate radii. After several iterations

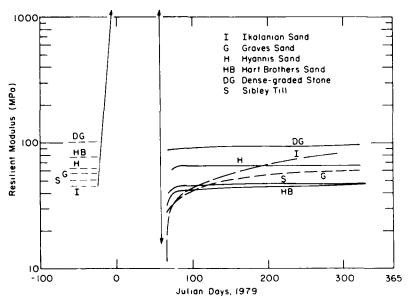


Figure 24. Interpretation of seasonal variation in resilient modulus of six test soils directly beneath asphalt pavement under 200-300 kPa plate pressure.

Table 7. Calculated resilient modulus (MPa) in upper layer of Hart Brothers sand beneath center of plate.

	Top 250 mm, 1979			Top 250 m	m, 1980
	244-283 kPa Plate pressure	530-590 kPa Plate pressure		197-279 kPa Plate pressure	331-605 kPa Plate pressur
30 October 1978	44.8	48.9	25 February 1980	670.4	793.3
13 February 1979	4872.5	4872.5	12 March 1980	122.5	180.8
6 March 1979	31.1	37.7	19 March 1980	23.1	26.1
13 March 1979	40.3	52.8	22 March 1980	18.4	20.9
21 March 1979	41.6	45.1	26 March 1980	19.8	22.9
28 March 1979	41.5	47.0	29 March 1980	20.0	21.6
4 April 1979	40.5	44.8	3 April 1980	27.6	29.4
24 April 1979	45.1	48.2	10 April 1980	25.8	27.4
7 May 1979	38.6	40.3	17 April 1980	26.9	28.6
29 May 1979	35.6	37.9	•		
25 July 1979	48.0	49.0			
27 September 1979	45.3	48.9			
20 November 1979	48.5	54.4			

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Table 8. Calculated resilient modulus (MPa) in upper layer of Hyannis sand beneath center of plate.

	Top 250	mm, 1979		Top 250 m	m, 1980
	214-281 kPa Plate pressure	512-597 kPa Plate pressure		196-379 kPa Plate pressure	439-560 kPa Plate pressur
31 October 1978	62.2	69.0	25 February 1980	1996.8	1996.8
12 February 1979	29,993.9	29.993.9	12 March 1980	85.6	104.8
7 March 1979	21.0	21.0	19 March 1980	76.8	82.8
12 March 1979	21.0	21.0	22 March 1980	65.9	76.6
20 March 1979	67.6	78.0	26 March 1980	65.8	72.4
27 March 1979	65.5	73.1	29 March 1980	63.5	70.8
3 April 1979	65.1	73.2	3 April 1980	62.1	67.9
23 April 1979	64.5	70.6	10 April 1980	65.0	72.5
7 May 1979	63.3	70.1	17 April 1980	62.0	68.0
29 May 1979	62.3	68.9	-		
24 July 1979	67.7	76.7			
27 September 1979	68.4	77.1			
19 November 1979	68.8	75.1			

Table 9. Calculated resilient modulus (MPa) in upper layer of Sibley till beneath center of plate.

	Top 250	mm, 1979		Top 250 mm, 1980		
	246–283 kPa Plate pressure	472-597 kPa Plate pressure		167-300 kPa Plate pressure	330–600 kPd Plate pressur	
30 October 1978	_	51.5	25 February 1980	3449.0	3449.0	
12 February 1979	8046.0	8046.0	12 March 1980	40.2	44.6	
7 March 1979	39.8	39.8	19 March 1980	39.4	41.1	
12 March 1979	40.1	43.9	22 March 1980	37.9	40.9	
20 March 1979	42.4	46.1	26 March 1980	39.5	_	
27 March 1979	43.9	48.2	29 March 1980	39.7	43.2	
3 April 1979	46.4	50.9	3 April 1980	40.7	44.3	
23 April 1979	46.5	50.7	10 April 1980	39.6	43.2	
8 May 1979	47.7	50.7	17 April 1980	42.3	45.3	
30 May 1979	44.6	48.9	•			
24 July 1979	49.1	51.6				
27 September 1979	43.4	47.0				
19 November 1979	46.7	50.5				

with slightly adjusted values of the moduli, reasonable stability of the resulting deflection basin can usually be obtained.

In the above procedure, the Type 1 model of NELAPAV, for linear moduli, is used. A computer program for linear elastic materials, MOD-COMP I, has been developed for application of NELAPAV in the backward approach (Irwin 1981). It has not been applied to the nonlinear materials of the Winchendon test sections, except to check and validate the concepts and operation of the program.

#### DISCUSSION

The reasonably good agreement of the postthaw basins is taken as evidence that the expressions for nonlinear resilient moduli derived from laboratory tests are acceptable. Thus the adopted laboratory procedures for determining seasonal variations in resilient modulus are seen as adequately validated for soils of the types tested, and the results of tests according to that procedure should provide a useful basis for evaluating and designing new and rehabilitated pavements in cold regions.

The application of materials characterizations in the form of expressions for nonlinear resilient modulus derived from laboratory tests requires use of a pavement response model that can account for the stress dependency of the modulus. NELAPAV has given good results in the analysis of the Winchendon field data and is seen as a useful analytical tool.

An important characteristic of the laboratorytest-derived expressions for resilient modulus is the further dependence of the modulus upon sitespecific environmental parameters that vary widely throughout the annual cycle of seasonal changes. The principal parameters are temperature and moisture tension. Consequently, assessment of the seasonal variation in the modulus prevailing in a material for which a laboratory nonlinear characterization has been developed requires not only a calculation of the stress in the material but field observation of temperature and moisture tension as well. Such field observations of conditions prevailing in the various layers in existing pavements can be obtained by installing sensors and collecting data over a complete annual cycle. Data obtained from undeveloped terrain where a new pavement is planned may be inapplicable to the future conditions after construction. An alternative to field data collection is to predict temperatures and moisture tensions by means of a mathematical model of the freezing and thawing process. The frost heave model of Guymon et al. (in prep.) can be used for this purpose.

While the analysis of the field data as presented herein engenders reasonable confidence in the laboratory procedures for determining resilient modulus and assessing its seasonal variation, implementation in engineering practice should await further confirmation. Work recently completed on airfield pavements at Albany County Airport, N.Y., will enhance the data base and is expected to provide further confidence in the methodology. That work will be presented in separate reports (Cole et al., in prep., Johnson et al. 1986).

#### **CONCLUSIONS**

The research results summarized in this report lead to the following conclusions:

- 1. The analysis of field loading tests on six paved soil test sections at Winchendon, Mass., provided evidence that laboratory procedures (Cole et al. 1986), developed under this research project for deriving nonlinear materials characterizations of the six soils in the frozen and thawed conditions, are acceptable. While the laboratory procedures are considered to be validated for soils of the types tested, further confirming evidence is needed. Evidence on other nonlinear materials will be forthcoming from work recently completed at Albany County Airport, N.Y.
- 2. To make use of nonlinear materials characterizations, one needs an appropriate pavement response model that is capable of accounting for the stress dependency of the resilient modulus. NELAPAV, a computer program for nonlinear elastic layered analysis of pavements, is found to be a useful analytical tool.
- 3. The numerical value of the resilient modulus prevailing in a frozen or thawed pavement material at a given time cannot be calculated with the sole aid of an appropriate expression for the modulus derived from laboratory tests, but requires assessment of prevailing environmental conditions, principally temperature and moisture tension. These parameters can be monitored throughout an annual cycle by means of sensors installed in existing pavements, or their values throughout the year may be forecast by means of the frost-heave model of Guymon et al. (in prep.).
- 4. Limited application of the backward approach, an analytical procedure for determining resilient modulus from field measurements of surface deflection, indicates the validity of the approach. A computer program, MODCOMP I, was developed to calculate moduli in linear elastic materials.

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# APPENDIX A: FIELD DATA Winchendon, Mass., Test Sections

Table A1. Data from repeated-load plate-bearing (RPB) tests, Ikalanian sand test section.

Resilient Displacement at Two Load Levels

30 October Load (kN): Radius (mm)		37.8	20 March 1979 Load (kN): Radius (mm)	Day 79) 18.7 Displaces	39.1 ment (mm)	7 May 1979 ( Load (kN): Radius (mm)	19.3	40.0 ment (mm)	19 November Load (kN): Radius (mm)	20.5	43.1
140	0.6147	1.1202	133	0.602	1.098	149	0.6868	1.3879	146	0.5321	0.9728
311	0.2692	0.5232	279	0.312	0.607	289	0.3048	0.6909	295	0.2794	0.5791
387	0.1732	0.3505	394	0.196	0.387	371	0.1858	0.4490	394	0.2012	0.4191
450	0.1359	0.2667	479	0.115	0.247	457	0.1304	0.3342	476	0.1539	0.3150
762	0.0470	0.0909	784	0.050	0.088	752	0.0620	0.1849	772	0.0632	0.1331
12 February	1979 (Day	43)	27 March 1979	(Day 86)		29 May 1979	(Day 149)				
Load (kN):		40.5	Load (kN):	18.01	40.03	Load (kN):	19.1	40.3			
Radius (mm)			Radius (mm)	Displacer		Radius (mm)	Displace	ment (mm)			
.mo.ros /	Diopideen		<u> </u>								
143	0.1251	0.1919	140	0.645	1.265	140	0.6413	1.2898			
302	0.0167	0.0329	279	0.401	0.826	289	0.3404	0.6985			
387	0.0211	0.0291	368	0.266	0.542	381	0.2026	0.4374			
464	0.0190	0.0280	464	0.180	0.362	473	0.1359	0.2801			
759	0.0195	0.0267	746	0.072	0.132	772	0.0530	0.1128			
,,,	0.0105	0.0207									
	79 (Day 66)		3 April 1979			24 July 1979					
Load (kN):	19.3	38.9	Load (kN):	19.1	40.0	Load (kN):	19.8	40.3			
	19.3			19.1	40.0 ment (mm)		19.8				
Load (kN): Radius (man	19.3 ) Displacem	ent (mm)	Load (kN): Radius (mm)	19.1 Displaces	ment (mmm)	Load (kN): Radius (mm)	19.8 Displace	40.3 ment (mm)			
Load (kN): Radius (see 140	19.3 ) Displaces 1.8265	2.6994	Load (kN): Radius (mm)	19.1 Displaces	ment (mm) 1.3842	Load (kN): Radius (mm)	19.8 Displace 0.5709	40.3 ment (mm) 1.1160			
Load (kN): Radius (mm 140 286	19.3 ) Displaces 1.8265 1.2258	2.6994 1.7419	Load (kN): Radius (mm) 140 292	19.1 Displaces 0.6451 0.3556	1.3842 0.7303	Load (kN): Radius (mma) 137 283	19.8 Displace 0.5709 0.2667	40.3 ment (mm) 1.1160 0.5588			
Load (kN): Radius (sea 140 286 375	19.3 ) Displacem 1.8265 1.2258 0.8668	2.6994 1.7419 1.1719	Load (kN): Radius (mm)  140 292 371	19.1 Displaces 0.6451 0.3556 0.2361	1.3842 0.7303 0.5017	Load (kN): Radius (mm) 137 283 378	19.8 Displace 0.5709 0.2667 0.1716	40.3 ment (mm) 1.1160 0.5588 0.3574			
Load (kN): Radius (mm)  140 286 375 467	19.3 ) Displaces 1.8265 1.2258 0.8668 0.5550	2.6994 1.7419 1.1719 0.7280	Load (kN): Radius (mm)  140 292 371 460	19.1 Displaces 0.6451 0.3556 0.2361 0.1678	1.3842 0.7303 0.5017 0.3536	Load (kN): Radius (mm)  137 283 378 470	19.8 Displace 0.5709 0.2667 0.1716 0.1179	40.3 ment (num) 1.1160 0.5588 0.3574 0.2371			
Load (kN): Radius (sea 140 286 375	19.3 ) Displacem 1.8265 1.2258 0.8668	2.6994 1.7419 1.1719	Load (kN): Radius (mm)  140 292 371	19.1 Displaces 0.6451 0.3556 0.2361	1.3842 0.7303 0.5017	Load (kN): Radius (mm) 137 283 378	19.8 Displace 0.5709 0.2667 0.1716	40.3 ment (mm) 1.1160 0.5588 0.3574			
Load (kN): Radius (mm  140 286 375 467	19.3 Displaces 1.8265 1.2258 0.8668 0.5550	2.6994 1.7419 1.1719 0.7280	Load (kN): Radius (mmn)  140 292 371 460 746	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609	1.3842 0.7303 0.5017 0.3536 0.1376	Load (kN): Radius (mm)  137 283 378 470	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507	40.3 ment (mm) 1.1160 0.5588 0.3574 0.2371 0.0936			
Load (kN): Radius (mma)  140 286 375 467 12 March 1	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71)	2.6994 1.7419 1.1719 0.7280	Load (kN): Radius (mmm)  140 292 371 460 746 23 April 197	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113)	1.3842 0.7303 0.5017 0.3536 0.1376	Load (kN): Radius (mm)  137 283 378 470 762	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507	40.3 ment (mm) 1.1160 0.5588 0.3574 0.2371 0.0936			
Load (kN): Radius (mm)  140 286 375 467 12 March 1 Load (kN):	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71)	2.6994 1.7419 1.1719 0.7280	Load (kN): Radius (mm)  140 292 371 460 746  23 April 197 Load (kN):	19.1 D1splaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5	1.3842 0.7303 0.5017 0.3536 0.1376	Load (kN): Radius (mm)  137 283 378 470 762  27 September Load (kN):	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day	40.3 ment (nm)  1.1160 0.5588 0.3574 0.2371 0.0936			
Load (kN): Radius (mma)  140 286 375 467 12 March 1	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71)	2.6994 1.7419 1.1719 0.7280	Load (kN): Radius (mmm)  140 292 371 460 746 23 April 197	19.1 D1splaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5	1.3842 0.7303 0.5017 0.3536 0.1376	Load (kN): Radius (mm)  137 283 378 470 762 27 September	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day	40.3 ment (nm)  1.1160 0.5588 0.3574 0.2371 0.0936			
Load (kN): Radius (mm  140 286 375 467 12 March 1 Load (kN): Radius (mm	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71) 20.5 ) Displacem	2.6994 1.7419 1.1719 0.7280 39.8 ment (mm)	Load (kN): Radius (mm)  140 292 371 460 746 23 April 197 Load (kN): Radius (mm)	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5 Displace	1.3842 0.7303 0.5017 0.3536 0.1376 ) 39.5 meent (mm)	Load (kN): Radius (mm)  137 283 378 470 762  27 September Load (kN): Radius (mm)	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day 20.0 Displace	40.3 ment (mm)  1.1160 0.5588 0.3574 0.2371 0.0936 270) 42.7 ement (mm)			
Load (kN): Radius (mm  140 286 375 467 12 March 1 Load (kN): Radius (mm	19.3 ) Displaces  1.8265 1.2258 0.8668 0.5550 979 (Day 71) 20.5 ) Displaces	2.6994 1.7419 1.1719 0.7280 39.8 ment (mm)	Load (kN): Radius (mm)  140 292 371 460 746 23 April 197 Load (kN): Radius (mm)	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113 18.5 Displace	1.3842 0.7303 0.5017 0.3536 0.1376 ) 39.5 ment (mm)	Load (kN): Radlus (mm)  137 283 378 470 762  27 September Load (kN): Radlus (mm)  146 286	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day 20.0 Displace 0.5779 0.3302	40.3 ment (nm)  1.1160 0.5588 0.3574 0.2371 0.0936 270) 42.7 ment (nm)  1.1731 0.6680			
Load (kN): Radius (mm  140 286 375 467 12 March 1 Load (kN): Radius (mm	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71) 20.5 ) Displacem	2.6994 1.7419 1.1719 0.7280 39.8 ment (mm)	Load (kN): Radius (mm)  140 292 371 460 746 23 April 197 Load (kN): Radius (mm)	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5 Displace	1.3842 0.7303 0.5017 0.3536 0.1376 ) 39.5 meent (mm)	Load (kN): Radlus (mm)  137 283 378 470 762  27 September Load (kN): Radlus (mm)  146 286 384	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day 20.0 Displace 0.5779 0.3302 0.2181	40.3 ment (mm)  1.1160 0.5588 0.3574 0.2371 0.0936  270) 42.7 ment (mm)  1.1731 0.6680 0.4516			
Load (kN): Radius (mm  140 286 375 467 12 March 1 Load (kN): Radius (mm  140 295 378	19.3 ) Displacem  1.8265 1.2258 0.8668 0.5550  979 (Day 71) 20.5 ) Displacem 0.589 0.594	2.6994 1.7419 1.1719 0.7280 39.8 ment (mm) 1.311 1.390	Load (kN): Radius (mmn)  140 292 371 460 746  23 April 197 Load (kN): Radius (mmn)	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5 Displace 0.7048 0.3149	1.3842 0.7303 0.5017 0.3536 0.1376 ) 39.5 ment (mm)	Load (kN): Radlus (mm)  137 283 378 470 762  27 September Load (kN): Radlus (mm)  146 286	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day 20.0 Displace 0.5779 0.3302 0.2181 0.1484	40.3 ment (nm)  1.1160 0.5588 0.3574 0.2371 0.0936 270) 42.7 ment (nm)  1.1731 0.6680			
Load (kN): Radius (mm  140 286 375 467 12 March 1 Load (kN): Radius (mm  140 295	19.3 ) Displacem 1.8265 1.2258 0.8668 0.5550  979 (Day 71) 20.5 ) Displacem 0.589 0.594 0.188	2.6994 1.7419 1.1719 0.7280 39.8 ment (wm) 1.311 1.390 0.419	Load (kN): Radius (mmn)  140 292 371 460 746  23 April 197 Load (kN): Radius (mmn)  133 289 371	19.1 Displaces 0.6451 0.3556 0.2361 0.1678 0.0609 9 (Day 113) 18.5 Displace 0.7048 0.3149 0.1999	1.3842 0.7303 0.5017 0.3536 0.1376 ) 39.5 ment (mm) 1.4097 0.6667 0.4225	Load (kN): Radlus (mm)  137 283 378 470 762  27 September Load (kN): Radlus (mm)  146 286 384	19.8 Displace 0.5709 0.2667 0.1716 0.1179 0.0507 1979 (Day 20.0 Displace 0.5779 0.3302 0.2181	40.3 ment (mm)  1.1160 0.5588 0.3574 0.2371 0.0936  270) 42.7 ment (mm)  1.1731 0.6680 0.4516			

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## Pavement and Subgrade Temperatures (°C)

Depth (mm)	30 Oct	12 Feb	7 Mar	12 Mar	20 Mar	27 Mar	3 Apr	23 Apr	7 May	29 May	24 July	27 Sep	19 Nov
Surface	15,2		3.1	0.5	19.9	8.0	7.2	36.7	32.7	39.9	31.3		
50			2.9	0.6	0.3	9.0	6.8	33.4	33.5	34.8	32.0		
210		-3.6	σ.8	0.1	2.2	2.4	3.3	16.1	21.1	20.8	31.4		
340		-3.1	0.0	1.5	1.5	1.7	2.9	11.9	17.7	17.5	31.1		
410		-2.4	0.0	0.0	1.0	1.2	2.8	11.1	17.0	16.9	30.8		
450		-1.0	0.0	0.0	0.5	0.6	3.0	10.3	16.3	16.6	30.1		
610		0.2	0.0	0.0	0.1	0.2	3.2	9.6	15.4	16.1	28.6		
690		0.7	0.1	0.1	0.0	0.1	3.2	8.9	14.7	15.7	27.5		
840		1.4	0.6	0.5	0.0	0.8	3.3	7.9	13.4	15.1	25.5		
1060		2.4	1.4	1.1	0.0	1.6	3.3	6.8	12.0	14.2	23.5		
1260		3.2	2.1	1.6	0.4	1.8	3.3	6.1	10.9	14.1	21.9		
1460		4.0	3.1	2.3	2.1	2.3	3.6	5.9	10.1	13.0	20.8		

#### Moisture Tension (kPa)

Depth (mag)	12 Feb	7 Mar	12 Mar	20 Mar	27 Mar	3 Apr	23 Apr	7_May	29 May	24 July	27 Sep	19 Ney
457 559		0 1.0	1.9	6.9 3.9	6.4 3.9	6.9 3.9	5.4 8.8	8.3 4.9	7.9 4.9	12.0 10.0		10.0 10.0

Table A2. Data from repeated-load plate-bearing (RPB) tests, Graves sand test section.

	197 <mark>8</mark> (Day-63)	)	21 March 1979			8 May 1979 (Da			19 November		
Load (kN):	18.9		Load (kN):	19.6	36.7	Load (kN):	19.1	40.0	Load (kN):	20.2	43.1
Radius (mm)	Displacemen	nt (mm)	Radius (mm)	Displaceme	ent (nom)	Radius (mm)	Displace	ment (mm)	Radius (mm)	Displace	ment (mm)
1.0	0.702/		137	0.860	1 661	140	0.7992	1.5989	143	0.6236	1.2129
140	0.7836		286		1.551	276	0.7992	0.8319	314	0.2997	0.6248
190	0.3708	not		0.464	0.762				403	0.2090	0.4420
394	0.2116	done	365	0.261	0.458	378	0.2194	0.4774			
444	0.1374	40	451	0.150	0.225	467	0.1345	0.2912	483	0.1499	0.3226
749	0.0414		737	0.036	0.062	759	0.0541	0.0925	794	0.0462	0.1036
12 February	1979 (Day 4)	3)	28 March 1979	Day 87)		30 May 1979 (	Day 150)				
Load (kN):	19.8	39.6	Load (kN):	19.5	40.0	Load (kN):	21.6	40.7			
Radius (mm)	Displacemen		Radius (mm)	Displaceme		Radius (mm)		ment (mm)			
Man (and)	DISPIACEME	ic (man)		D-DP I GCC III	VIII (IIIII)			<u> </u>			
137	0.0605	0.1236	140	0.750	1.730	143	0.7397	1.5182			
308	0.0194	0.0361	295	0.434	0.965	279	0.3785	0.8026			
384	0.0139	0.0291	384	0.295	0.474	381	0.2129	0.4865			
464	0.0120	0.0260	470	0.175	0.423	467	0.1345	0.3120			
762	0.0136	0.0230	765	0.034	0.082	768	0.0586	0.0970			
6 March 197	(Day 65)		4 April 1979	(Day 94)		25 July 1979	(Day 206)				
6 March 1979 Load (kN):	Day 65)	18.2	4 April 1979 Load (kN):	18.5	38.9	25 July 1979 Load (kN):	(Day 206) 20.7	42.5			
							20.7	42.5 ment (mm)			
Load (kN): Radius (mm)	7.3 Displacemen	nt (mmm)	Load (kN): Radius (mm)	18.5 Displaceme	nt (mm)	Load (kN): Radius (mm)	20.7 Displace	ment (mm)			
Load (kN): Radius (mm)	7.3 Displacemen	nt (mm) 1.0693	Load (kN): Radius (mm)	18.5 Displaceme	1.6423	Load (kN): Radius (mm)	20.7 Displace 0.7261	ment (mm)			
Load (kN): Radius (mm) 143 289	7.3 Displacement 0.4735 0.2258	1.0693 0.5484	Load (kN): Radius (mm) 136 289	18.5 Displaceme 0.8062 0.4166	1.6423 0.9144	Load (kN): Radius (mm)  143 270	20.7 Displace 0.7261 0.3708	1.4440 0.8065			
Load (kN): Radius (mm)  143 289 372	7.3 Displacemen 0.4735 0.2258 0.1456	1.0693 0.5484 0.3675	Load (kN): Radius (mm)  136 289 368	18.5 Displaceme: 0.8062 0.4166 0.3097	1.6423 0.9144 0.6548	Load (kN): Radius (mm)  143 270 381	20.7 Displace 0.7261 0.3708 0.1716	ment (mm)			
Load (kN): Radius (mm)  143 289 372 454	7.3 Displacement 0.4735 0.2258	1.0693 0.5484	Load (kM): Radius (mm)  136 289 368 457	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955	1.6423 0.9144 0.6548 0.4243	Load (kN): Radius (mm)  143 270 381 467	20.7 Displace 0.7261 0.3708 0.1716 0.1123	1.4440 0.8065			
Load (kN): Radius (mm)  143 289 372	7.3 Displacemen 0.4735 0.2258 0.1456	1.0693 0.5484 0.3675	Load (kN): Radius (mm)  136 289 368	18.5 Displaceme: 0.8062 0.4166 0.3097	1.6423 0.9144 0.6548	Load (kN): Radius (mm)  143 270 381	20.7 Displace 0.7261 0.3708 0.1716	1.4440 0.8065 0.3806			
Load (kN): Radius (mm)  143 289 372 454 749	7.3 Displacement 0.4735 0.2258 0.1456 0.0860	1.0693 0.5484 0.3675 0.1803	Load (kM): Radius (mm)  136 289 368 457 752	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496	1.6423 0.9144 0.6548 0.4243	Load (kN): Radius (mm)  143 270 381 467 759	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440	1.4440 0.8065 0.3806 0.2441 0.0902			
Load (kN): Radius (mm)  143 289 372 454 749  13 March 19	7.3 Displacement 0.4735 0.2258 0.1456 0.0860 	1.0693 0.5484 0.3675 0.1803	Load (kM): Radius (mm)  136 289 368 457 752 24 April 197	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114)	1.6423 0.9144 0.6548 0.4243 0.0834	Load (kN): Radius (mm)  143 270 381 467 759 27 September	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440	1.4440 0.8065 0.3806 0.2441 0.0902			
Load (kN): Radius (mmn)  143 289 372 454 749  13 March 19 Load (kN):	7.3 Displacement  0.4735 0.2258 0.1456 0.0860  79 (Day 72) 19.1	1.0693 0.5484 0.3675 0.1803	Load (kM): Radius (mm)  136 289 368 457 752  24 April 197  Load (kN):	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7	1.6423 0.9144 0.6548 0.4243 0.0834	Load (kN): Radius (mm)  143 270 381 467 759  27 September Load (kN):	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9	1.4440 0.8065 0.3806 0.2441 0.0902			
Load (kN): Radius (mm)  143 289 372 454 749  13 March 19	7.3 Displacement 0.4735 0.2258 0.1456 0.0860 	1.0693 0.5484 0.3675 0.1803	Load (kM): Radius (mm)  136 289 368 457 752 24 April 197	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114)	1.6423 0.9144 0.6548 0.4243 0.0834	Load (kN): Radius (mm)  143 270 381 467 759 27 September	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9	1.4440 0.8065 0.3806 0.2441 0.0902			
Load (kN): Radius (mmn)  143 289 372 454 749  13 March 19 Load (kN):	7.3 Displacement  0.4735 0.2258 0.1456 0.0860  79 (Day 72) 19.1	1.0693 0.5484 0.3675 0.1803	Load (kM): Radius (mm)  136 289 368 457 752  24 April 197  Load (kN):	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7	1.6423 0.9144 0.6548 0.4243 0.0834	Load (kN): Radius (mm)  143 270 381 467 759  27 September Load (kN):	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9	1.4440 0.8065 0.3806 0.2441 0.0902			
Load (kN): Radius (mm)  143 289 372 454 749 13 March 19 Load (kN): Radius (mm)	7.3 Displacemen 0.4735 0.2258 0.1456 0.0860  79 (Day 72) 19.1 Displacemen	1.0693 0.5484 0.3675 0.1803 	Load (kM): Radius (mm)  136 289 368 457 752 24 April 197 Load (kN): Radius (mm)	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7 Displaceme	1.6423 0.9144 0.6548 0.4243 0.0834 39.1	Load (kN): Radius (mm)  143 270 381 467 759 27 September Load (kN): Radius (mm)	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9 Displace	1.4440 0.8065 0.3806 0.2441 0.0902 270) 43.4 ment (mm)			
Load (kN): Radius (mm)  143 289 372 454 749  13 March 19 Load (kN): Radius (mm)	7.3 Displacement 0.4735 0.2258 0.1456 0.0860 	1.0693 0.5484 0.3675 0.1803  41.1 at (mm)	Load (kM): Radius (mm)  136 289 368 457 752 24 April 197 Load (kN): Radius (mm)	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7 Displaceme	1.6423 0.9144 0.6548 0.4243 0.0834 39.1 ent (mmn)	Load (kN): Radius (mm)  143 270 381 467 759  27 September Load (kN): Radius (mm)	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9 Displace 0.6337	1.4440 0.8065 0.3806 0.2441 0.0902 270) 43.4 ement (mm)			
Load (kN): Radius (mm)  143 289 372 454 749  13 March 19 Load (kN): Radius (mm)  133 289 368	7.3 Displacemen 0.4735 0.2258 0.1456 0.0860  79 (Day 72) 19.1 Displacemen 0.550 0.648 0.206	1.0693 0.5484 0.3675 0.1803  41.1 nt (mm) 1.276 1.435 0.438	Load (kM): Radius (mm)  136 289 368 457 752  24 April 197 Load (kN): Radius (mm)  143 298	18.5 Displaceme 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7 Displaceme 0.7296 0.3505	1.6423 0.9144 0.6548 0.4243 0.0834 39.1 ent (mm) 1.5851 0.7620	Load (kN): Radius (mm)  143 270 381 467 759  27 September Load (kN): Radius (mm)	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9 Displace 0.6337 0.3073	1.4440 0.8065 0.3806 0.2441 0.0902 270) 43.4 ment (mm)			
Load (kN): Radius (mm)  143 289 372 454 749  13 March 19 Load (kN): Radius (mm)  133 289	7.3 Displacemen 0.4735 0.2258 0.1456 0.0860  79 (Day 72) 19.1 Displacemen 0.550 0.648	1.0693 0.5484 0.3675 0.1803  41.1 at (mm)	Load (kM): Radius (mm)  136 289 368 457 752  24 April 197 Load (kN): Radius (mm)  143 298 384	18.5 Displaceme: 0.8062 0.4166 0.3097 0.1955 0.0496 9 (Day 114) 18.7 Displaceme: 0.7296 0.3505 0.2129	1.6423 0.9144 0.6548 0.4243 0.0834 39.1 ent (mm) 1.5851 0.7620 0.4774	Load (kN): Radius (mm)  143 270 381 467 759  27 September Load (kN): Radius (mm)  146 289 384	20.7 Displace 0.7261 0.3708 0.1716 0.1123 0.0440 1979 (Day 20.9 Displace 0.6337 0.3073 0.2052	1.4440 0.8065 0.3806 0.2441 0.0902 270) 43.4 mment (mm) 1.3130 1.1049 0.4387			

CONTROL BENEVICE CONSISSES CONTROL CONTROL BENEVICES

# Pavement and Subgrade Temperatures (°C)

Depth (mm)	30 Oct	12 Feb	6 Mar	13 Mar	21 Mar	28 Mar	4 Apr	24 Apr	8 May	30 <b>Ma</b> y	25 July	27 Sep	19 Nov
Surface	12.3	-7.4	5.5	-1.1	3.9	-1.1	1.0	13.5	14.3	15.9	26.9	12.2	7.1
51		-10.1	4.1	-0.4	4.0	-0.8	1.0	14.7	18,2	17.7	28.2	12.2	5.6
152		-8.7	1.5	0.2	2.6	0.1	0.2	11.5	17.0	18.4	28.8	14.7	5.3
305		-4.4	-0.4	0.0	0.4	0.6	0.8	11.6	17.6	19.1	29.6	18.4	6.3
457		-0.5	-0.4	0.0	-0.4	-0.3	0.4	10.5	16.1	18.2	28.5	19.0	7.3
610		0.5	-0.4	0.0	-0.4	-0.9	-0.4	9.0	14.5	17.1	26.9	18.8	7.8
762		1.4	0.1	0.3	-0.1		0.1	7.3	12.7	15.8	25.1	18.5	8.3
914		1.7	0.5	0.7	0.4		0.3	6.4	11.6	15.1	23.6	18.5	9.0
1067		2.2	1.4	1.1	0.7		0.6	5.7	10.9	14.6	22.5	18.5	9.3
1219		2.4	1.7	1.4	1.1		1.1	5.1	10.0	14.2	21.1	18.5	9.8
1371		2.8	2.1	1.8	1.4		1.4	4.9	9.5	13.7	20.3	18.5	10.2
1524		3.2		2.1	1.7		1.7	4.7	9.0	13.4	19.5	18.3	10.5

7 Sep 19 No	27 Sep	25 July	30 May	8 May	24 Apr	4 Apr	28 Mar	21 Mar	13 Mar	6 Mar	12 Feb	(mm)_
10.5 12.0	10.5	14.0	9.8	11.8	11.8	7.8	6.8	5.4	4.4	0	1.9	152
12.0 10.0	12.0	14.5	9.8	11.8	11.8	7.8	6.4	5.9	3.9	0	11.8	305
10.0	10.0	12.0	8.3	9.8	9.8	6.9	5.9	7.4	7.8	0	12.3	610
1.5	1.5	3.5	0	2.8	2.5	0	0	1.9	0	1.9	3.9	914
l		14.5 12.0	9.8 8.3	11.8 9.8	11.8	7.8 6.9	6.4 5.9	5.9 7.4	3.9 7.8	0	11.8 12.3	305 610

Table A3. Data from repeated-load plate-bearing (RPB) tests, Hart Brothers sand test section.

30 October 19	n 70 (Day 63)		21 March 1979	(Day 80)		7 May 1979 (D	ay 127)		20 November		
	17.8	37.8	Load (kN):	18.9	40.0	Load (kN):	18.9	40.0	Load (kN):	20.0	42.7
	Displacemen		Radius (mms)	Displaceme		Radius (mm)	Displace	ment (mona)	Radius (mm)	Displace	ment (mm)
Maditus (IIIII)	DISPIACEMEN	C (mm)	- Cardina (-a)		<u> </u>						
140	0.6515	1.1989	146	0.671	1,297	139	0.7224	1.3497	146	0.5220	0.9931
305	0.2616	0.4902	299	0.279	0.616	283	0.2794	0.5639	305	0.2743	0.5486
		0.3073	384	0.159	0.329	375	0.1561	0.3096	400	0.1910	0.3861
387	0.1526	0.30/3	470	0.094	0.182	470	0.1095	0.2094	486	0.1387	0.2896
457	0.1110		768	0.023	0.052	756	0.0496	0.0981	784	0.0472	0.1105
762	0.0419	0.0853	/08	0.023	0.052	750	0.0470				
13 February	1979 (Day 63		28 March 1979	(Day. 37)		29 May 1979	'Day 149)				
Load (KN):	20 (Day 4)	37.4	Load (kN):	19.3	40.5	Load (kN):	18.9	40.9			
			Radius (mm)	Displaceme		Radius (mm)	Displaces	ment (mm)			
Radius (mona)	Displacemen	E (max)	Kadius (mm)	Displacem	Sire (ana)	reduzed (mm)					
127	0.0946	0.0934	143	0.688	1.370	146	0.6836	1.3179			
286	0.0032	0.0194	302	0.371	0.705	289	0.2692	0.5512			
362	0.0032	0.0140	391	0.222	0.468	394	0.1510	0.3058			
	0.0021	0.0100	479	0.137	0.261	476	0.1096	0.2205			
445	0.002	0.0063	679	0.112	0.088	775	0.0474	0.0947			
730		0.0063	0/7	0.112	0.000	.,,,					
6 March 1979	(Lay 65)		4 April 1979	(Day 94)		25 July 1979	(Day 206)				
								42.4			
Load (kN):	18.7	40.5	Load (kN):	18 5	41.4	Load (kN):	20.7	42.4			
Load (kN):	18.7	40.5 at (mm)	Load (kN): Radius (zmm)	18.5 Displaceme		Load (kN): Radius (mm)		ment (mm)			
Load (kN): Radius (mm)	18.7 Displacemen		Load (kN): Radius (mm)	18.5 Displaceme							
Radius (mm)	Displacemen	nt (mena)									
Radius (mm)	Displacement 0.6349	1.2391	Radius (mm)	Displaceme	ent (mma)	Radius (mm)	Displace	ment (mm)			
Radius (mm) 137 289	0.6349 0.2903	1.2391 0.4516	Radius (mm) 143 298	0.7005 0.3556	1.3531 0.7366	Radius (mm)	Displace	ment (mm)			
Radius (mm) 137 289 368	0.6349 0.2903 0.1456	1.2391 0.4516 0.1976	Radius (mm) 143 298 384	0.7005 0.3556 0.2155	1.3531 0.7366 0.4613	140 270 375	0.7050 0.3480	1.2690 0.6706			
Radius (mm)  137 289 368 457	0.6349 0.2903 0.1456 0.0490	1.2391 0.4516 0.1976 0.0500	Radius (mma) 143 298 384 470	0.7005 0.3556 0.2155 0.1304	1.3531 0.7366 0.4613 0.2857	Radius (mm) 140 270	0.7050 0.3480 0.1613	1.2690 0.6706 0.3135			
Radius (mm) 137 289 368	0.6349 0.2903 0.1456	1.2391 0.4516 0.1976	Radius (mm) 143 298 384	0.7005 0.3556 0.2155	1.3531 0.7366 0.4613	Radius (mm) 140 270 375 457	0.7050 0.3480 0.1613 0.1068	1.2690 0.6706 0.3135 0.2108			
Radius (mm)  137 289 368 457 759	0.6349 0.2903 0.1456 0.0490 0.0089	1.2391 0.4516 0.1976 0.0500	Radius (mma) 143 298 384 470	0.7005 0.3556 0.2155 0.1304 0.0496	1.3531 0.7366 0.4613 0.2857 0.1116	Radius (mm) 140 270 375 457	0.7050 0.3480 0.1613 0.1068 0.0451	1.2690 0.6706 0.3135 0.2108 0.0902			
Radius (mm)  137 289 368 457 759  13 March 197	0.6349 0.2903 0.1456 0.0490 0.0089	1.2391 0.4516 0.1976 0.0500 0.0262	143 298 384 470 762	0.7005 0.3556 0.2155 0.1304 0.0496	1.3531 0.7366 0.4613 0.2857	Radius (mm)  140 270 375 457 768	0.7050 0.3480 0.1613 0.1068 0.0451	1.2690 0.6706 0.3135 0.2108 0.0902			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN):	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8	1.2391 0.4516 0.1976 0.0500 0.0262	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN):	0.7005 0.3556 0.2155 0.1304 0.0496	1.3531 0.7366 0.4613 0.2857 0.1116	Radius (mm)  140 270 375 457 768  27 September	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2	1.2690 0.6706 0.3135 0.2108 0.0902			
Radius (mm)  137 289 368 457 759  13 March 197	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8	1.2391 0.4516 0.1976 0.0500 0.0262	Radius (mm)  143 298 384 470 762 24 April 197	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm)	Radius (mm)  140 270 375 457 768  27 September Load (kN): Radius (mm)	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm)			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN):	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8	1.2391 0.4516 0.1976 0.0500 0.0262	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN):	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3 Displacem	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm)	Radius (mm)  140 270 375 457 768  27 September Load (kN): Radius (mm)	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace 0.6126	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm)			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN): Radius (mm)	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8 Displacement	1.2391 0.4516 0.1976 0.0500 0.0262 41.8	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN): Radius (mm)	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3 Displacem	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm)	Radius (mm)  140 270 375 457 768  27 September Load (RN): Radius (mm)  146 318	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace 0.6126 0.2388	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm) 1.1802 0.5309			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN): Radius (mm)	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8 Displacement	1.2391 0.4516 0.1976 0.0500 0.0262 41.8 at (mm)	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN): Radius (mm)	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3 Displacem	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm)	Radius (mm)  140 270 375 457 768  27 September Load (RN): Radius (mm)  146 318 397	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace 0.6126 0.2388 0.1523	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm) 1.1802 0.309 0.3226			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN): Radius (mm)  146 305 400	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8 Displaceme! 0.554 0.559 0.135	1.2391 0.4516 0.1976 0.0500 0.0262 41.8 at (mm) 1.003 1.016 0.271	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN): Radius (mm)  137 289	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3 Displacem 0.6839 0.3277	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm)	Radius (mm)  140 270 375 457 768  27 September Load (kN): Radius (mm)  146 318 397 492	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace 0.6126 0.2388 0.1523 0.1026	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm) 1.1802 0.5309 0.3226 0.2122			
Radius (mm)  137 289 368 457 759  13 March 197 Load (kN): Radius (mm)  146 305	0.6349 0.2903 0.1456 0.0490 0.0089 79 (Day 72) 19.8 Displacement	1.2391 0.4516 0.1976 0.0500 0.0262 41.8 nt (mm) 1.003 1.016	Radius (mm)  143 298 384 470 762  24 April 197 Load (kN): Radius (mm)  137 289 375	0.7005 0.3556 0.2155 0.1304 0.0496 9 (Day 114) 19.3 Displacem 0.6839 0.3277 0.1942	1.3531 0.7366 0.4613 0.2857 0.1116 40.3 ent (mm) 1.2684 0.6553 0.3923	Radius (mm)  140 270 375 457 768  27 September Load (RN): Radius (mm)  146 318 397	0.7050 0.3480 0.1613 0.1068 0.0451 1979 (Day 20.2 Displace 0.6126 0.2388 0.1523	1.2690 0.6706 0.3135 0.2108 0.0902 270) 42.7 ment (mm) 1.1802 0.309 0.3226			

# Pavement and Subgrade Temperatures (°C)

Depth (mm)	30 Oct	13 Feb	6 Mar	13 Mar	21 Mar	28 Mar	4 Apr	24 Apr	7 May	29 May	25 July	27 Sep	20 Nov
Surface	20.9	-6.8	7.0	1.0	9.3	-0.4	7.7	19.5	44.9	33.4	29.1	13.1	6.7
51		-7.9	5.1	-0.1	8.3	-0.5	5.4	19.5	36.3	33.6	30.2	13.7	4.8
152		-9.1	2.9	-0.2	5.6	0.4	1.7	13.9	29.3	27.9	29.1	14.7	4.8
305		-7.2	0.0	-0.1	2.9	1.0	1.2	11.4	20.7	20.9	28.3	16.4	5.0
457		-4.9	-0.2	-0.1	1.5	1.5	1.7	11.8	16.9	17.5	28.7	18.6	6.2
610		-2.5	-0.2	-0.2	0.0	0.9	1.4	10.8	15.5	16.6	27.8	18.9	6.9
762		-1.0	-0.1	-0.2	0.0	0.0	1.0	9.6	14.5	16.2	26,5	18.8	7.4
914		0.0	-0.1	-0.3	0.0	-0.7	0.6	8.3	13.5	15.7	25.1	18.5	7.9
1067		0.5	0.0	-0.2	-0.1	-0.7	0.5	7.5	12.7	15.2	23.9	18.4	8.2
		1.2	0.2	0.0	0.2	-0.4	0.7	6.7	11.9	14.8	22.9	18.3	8.7
1219		_						6.3	11.1	14.4	21.8	18.3	9.1
1371		1.7	0.6	0.4	0.6	0.0	1.0						
1524		1.7	2.0	0.8	0.9	0.4	1.2	5.8	10.6	14.1	21.0	18.3	9.3

Depth (man)	13 Feb	6 Mar	13 Mar	21 Mar	28 Mar	4 Apr	24 Apr	7 May	29 May	25 July	27 Sep	20 Nov
152 305 610	5.9 1.9 1.9	0 0 8.8	5.9 4.4 1.4	5.4 8.3 3.4	7.9 7.4 4.9	6.4 7.4 6.9	9.8 10.3 9.8	7.9 9.8 9.8	6.9 7.4 7.4	12.5 13.0 11.0	10.0 10.0 8.4	10.0 10.0 1J.0
914	9.8	10.8	0	1.0	1.0	2.4	4.9	4.4	3.9	6.5	5.0	13.0

Table A4. Data from repeated-load plate-bearing (RPB) tests, Hyannis sand test section.

31 October 1 Load (kN): Radius (mm)	15.6	38.9	20 March 197 Load (kN):	19.1	40.0	7 May 1979 Load (kN):	19.6	39.4	19 November Load (kN):	20.0	43.1
Madius (mm)	Displacem	ent (mm)	Radius (mma)	Displacem	ent (mm)	Radius (mm.)	Displaces	ment (mm)	Radius (mm.)	Displace	ment (mm)
140	0.4699	0.8966	137	0.425	0.839	146	0.6202	1.1697	146	0.4013	0.8242
292	0.3073	0.5969	283	0.425	0.521	302	0.0202	0.4902		0.4013	
362	0.2233	0.4572	375	0.168	0.321	391	0.1497		289		0.5359
432	0.2233							0.3032	394	0.1859	0.3734
743		0.3667	457	0.108	0.197	476	0.1068	0.2136	476	0.1359	0.2819
743	0.0571	0.1229	753	0.024	0.045	772	0.0439	0.0879	772	0.0541	0.1173
12 February	1979 (Day	43)	27 March 197	79 (Day <b>86</b> )	)	29 May 1979	(Day 149)				
Load (kN):	20	40.0	Load (kN):	19.1	40.0	Load (kN):	19.8	40.7			
Radius (mms)	Displacem	ent (mm)	Radius (mm)	Displacem	ent (mm)	Radius (mm)	Displacen	ent (mm)			
143	0.0772	0.1095	140	0.423	0.874	133	0.5992	1.3087			
299	0.0097	0.0174	286	0.267	0.579	267	0.3150	0.6248			
378	0.0090	0.0148	378	0.196	0.342	365	0.1884	0.3794			
457	0.0080	0.0117	464	0.136	0.283	448	0.1276	0.2552			
749	0.0010	0.0126	749	0.051	0.106	752	0.0496	0.1026			
7 March 1979	(Day 66)		3 April 1979	(Day 93)		24 July 1979	(Day 205)	1			
Load (kN):	19.1	41.4	Load (kN):	18.2	40.3	Load (kN):	19.8	42.3			
Radius (mm)	Displacem	ent (mm)	Radius (mm)	Displacem		Radius (mms)	Displaces				
140	0.6915	1.7930	140	0.4029	0.8800	143	0.5217	1.0860			
292·	0.4290	1,2322	292	0.2616	0.5740	283	0.2413	0.4826			
378	0.3120	0.9499	375	0.1948	0.4181	387	0.1394	0.2955			
467	0.223	0.7420	470	0.1387	0.3120	473	0.0985	0.2025			
756			762	0.0451	0.1150	765	0.0361	0.0846			
12 March 197	9 (Dev 71)		23 April 197	19 (Day 113	`	27 September	- 1979 (Day	270)			
Load (kN):	19.8	41.8	Load (kN):	18.9	39.6 7	Load (kN):	20.5	43.6			
Radius (mm)			Radius (mm)			Radius (mm)					
		<u></u>		DIOPIGCE			DIOPIUCES	actic (may)			
133	0.458	1.029	143	0.5609	1.1734	143	0.5883	1.0991			
276	0.552	1.340	286	0.2743	0.5969	286	0.2870	0.5652			
368	0.175	0.500	381	0.1729	0.3626	378	0.1884	0.3484			
445	0.129	0.419	467	0.1206	0.2496	470	0.1234	0.2593			
753	0.029	0.125	759	0.0496	0.0947	759	0.0530	0.0992			

# Pavement and Subgrade Temperatures (°C)

Depth (mm)	31 Oct	12 Feb	7 Mar	12 Mar	20 Mar	27 Mar	3 Apr	23 Apr	7 May	29 May	24 July	<u>27 Se</u> p	19 Nov
Surface	4.6	-9.4	none	6.3	23.5	7.1	6.7	27.6	33.7	31.9	34.9	27.6	6.4
51		-8.7	none	4.0	19.0	9.1	6.5	29.2	36.0	33.5	35.7	29.3	8.0
152		-10.3	none	-1.8	10.3	0.6	5.1	18.1	20.0	20.0	27.6	20.2	6.1
305		-7.1	none	-0.1	4.9	3.5	2.0	17.7	22.9	21.3	31.3	21.0	7.8
457		-5.5	none	-0.4	0.6	2.0	1.7	11.6	17.5	17.5	29.7	18.7	6.9
610		-3.9	none	-0.4	-0.2	1.4	1.3	9.6	18.6	16.7	28.5	18.8	7.2
762		-1.4	none	-0.5	-0.2	0.5	0.8	8.3	14.3	16.1	26.8	18.8	7.8
914		-0.5	none	-0.2	-0.2	0.0	0.4	7.2	13.1	15.4	25.3	18.8	8.3
1067		0.1	none	-0.1	0.0	0.1	0.4	6.4	12.0	14.8	23.9	18.8	8.8
1219		0.5	none	0.3	0.4	0.4	0.7	5.7	11.1	14.2	22.9	18.8	9.2
1371		~-	none	0.6	0.8	0.8	1.1	5.0	10.3	13.7	21.7	18.7	9.6
1524			none	1.0	1.1	1.1	1.4	4.6	9.6	13.2	20.8	18.6	10.0

(man)	12 Feb	7 Mar	12 Mar	20 Mar	27 Mar	3 Apr	23 Apr	7 May	29 May	24 July	<u>27 Se</u> p	<u>19 No</u> v
559	64	3	3	6	4.4	4	7.8	6.8	6	6.0	4.5	12.0
711	7.8	8	7.8	7.8	8	8	6	7.4	4	8.0	3.0	

Table A5. Data from repeated-load plate-bearing (RPB) tests, dense-graded stone test section.

31 October !	978 (Day-63	)	20 March 1979	(Day 79)		7 May 1979 (I	ay 127)		19 November		
Load (kN):		40.0	Load (kN):	19.1	40.9	Load (kN):	19.3	40.5	Load (kN):	20.0	43.6
Radius (mm)			Radius (mm)	Displacem	ent (mem.)	Radius (mm)	Displace	ment (mm)	Radius (mm)	Displace	ment (mm)
									1/0	0.3404	0.6363
146	0.3810	0.6362	137	0.394	0.760	146	0.4367	0.8632	149	0.1880	0.3759
298	0.1872	0.3912	276	0.282	0.551	292	0.2006	0.4115	308	0.1860	0.2743
368	0.1387	0.2769	375	0.187	0.386	387	0.1123	0.2477	410		0.2080
444	0.0105	0.2329	457	0.140	0.280	497	0.0766	0.1636	486	0.0942 0.0282	0.1016
743	0.0361	0.0836	756	0.037	0.103	772	0.0361	0.0789	791	0.0282	0.1016
12 February	1979 (Day 4	3)	27 March 197	9 (Day 86)		29 May 1979	(Day 149)				
Load (kN):	19.3	40.5	Load (kN):	19.1	40.0	Load (kN):	18.9	41.1			
Radius (mm)			Radius (mm)	Displacem	ent (mm)	Radius (mm)	Displace	ment (mm)_			
140	0.0648	0.0873	137	0.384	0.720	143	0.4370	0.8616			
289	0.0135	0.0181	289	0.254	0.477	286	0.2210	0.4470			
375	0.0076	0.0128	378	0.183	0.341	387	0.1316	0.2723			
449	0.0062	0.0120	464	0.129	0.244	470	0.0874	0.1844			
740	0.0062	0.0115	753	0.059	0.091	775	0.0361	0.0761			
7 March 197	9 (Day 66)		3 April 1979	(Day 93)		24 July 1979					
Load (kN):	19.6	41.8	Load (kh):	18.2	40.4	Load (kN):	20.0	42.5			
Radius (mm)	Displaceme	nt (mm)	Radius (mm)	Displacem	ent (mm)	Radius (mm)	Displace	ment (mm)			
						146	0.4679	0.9092			
140	0.3854	0.7234	136	0.3300	0.6499	279	0.2032	0.3835			
292	0.2323	0.5032	276	0.2464	0.4724	394	0.1058	0.2090			
381	0.1803	0.3640	362	0.1832	0.3613	489	0.0790	0.1539			
464	0.137	0.2740	451	0.1262	0.2677	781	0.0395	0.0710			
759			746	0.0451	0.1105	761	0.0373	0.0710			
12 March 19	79 (Day 71)		23 April 197	9 (Day 113)	•	27 September	1979 (Day	270)			
Load (kN):		42.2	Load (kN):	18.5	40.5	Load (kN):	20.2	43.6			
	Displaceme	ent (mm)	Radius (mm)	Displacem	ent (mm)	Radius (mm)	Displace	ment (mm)			
	0.400		1/3	0 / 205	0.0770	1/0	0.3732	0.7423			
146	0.408	0.791	143	0.4285	0.8739	149	0.2007	0.4089			
305	0.508	1.048	295	0.2108	0.4242	286	0.1290	0.2426			
394	0.164	0.355	384	0.1368	0.2709	381	0.0915	0.1831			
470	0.139	0.291	470	0.0887	0.1719	470	0.0383	0.0677			
787	0.044	0.085	765	0.0384	0.0620	768	0.0303	3.0077			

# Pavement and Subgrade Temperatures (°C)

Depth (mm)	31 Oct	12 Feb	7 Mar	12 Mar	20 Mar	27 <u>Mar</u>	3 Apr	23 Apr	7 May	29 May	24 July	27 Sep	19 Nov
Surface	7.2	-6.8	4.5	6.1	21.1	12.0	8.6	28.8	33.8	32.3	40.0	31.2	8.3
51		~8.6		4.4	20.5	14.6	8.4	31.3	36.7	33.8	41.9	29.1	9.5
152													
305				-0.4	2.9	5.7	4.1	15.6	20.8	20.6	31.0	20.1	7.0
457		-6.1		-0.3	1.4	4.4	3.7	11.2	16.9	17.2	29.4	18.4	6.6
610		~1.9		-0.3	0.4	4.2	3.6	9.4	15.0	16.2	28.2	18.4	7.0
762		~1.3	-0.4	-0.2	~0.4	3.7	3.4	8.2	13.7	15.4	26.6	18.5	7.7
914		~0.2	-0.2	-0.1	-0.4	2.9	3.2	7.0	12.4	14.7	25.1	18.5	8.1
1067		0.4	-0.3	0.4	~0.1	2.3	2.9	6.1	11.2	14.0	23.7	18.4	8.5
1219		1.0	0.0	0.7	0.4	1.7	2.5	5.0	10.0	13.2	22.5	18.5	9.0
1371		1.4	0.3	1.1	0.8	1.5	2.4	4.3	9.0	12.7	21.3	18.4	9.5
1524		1.7	0.5	1.1	1.0	1.6	2.3	4.0	8.4	12.1	20.6	18.4	9.8

Depth (mm)	12 Feb	7 Mar	12 Mar	20 Mar	27 Mar	3 Apr	_23 Apr	7 May	29 May	24 July	27 Sep	19 Nov
559	43.0	0	0	0	0	0	5.9	0	4.9	6.0	5.0	
711	24.5	0	0	0	0	0	0	0	3.4	4.0	3.5	

# Table A6. Data from repeated-load plate-bearing (RPB) tests, Sibley till test section.

# Resilient Displacement at Two Load Levels

30 October i Load (kN): Radius (mm)	34.5		20 March 1979 Load (kN): Radius (mm)	Day 79) 19.3 Displaceme	39.8 ent (mm)	8 May 1979 ( Load (kN): Radius (mm)	19.8	40.9 ment (mm)	19 November Load (kN): Radius (mm)	20.0	323) 43.1 ment (mm)
140	1.1735		143	0.924	1.663	133	0.4609	0.9761	149	0.4470	0.8725
298	0.5994		305	0.414	0.756	270	0.2032	0.4724	308	0.1829	0.3962
349	0.3429	not	387	0.196	0.409	352	0.0955	0.2426	403	0.1110	0.2565
447	0.2043	done	467	0.128		441	0.0513		489	0.1710	0.1775
743					0.229	441	0.0513	0.1289	683	0.0226	0.0541
743	0.0312		768	0.014	0.025				003	0.0220	0.0341
12 February	1979 (Day 4	3)	27 March 1979	(Day 86)		30 May 1979	(Day 150)				
Load (kN):	19.8	41.4	Load (kN):	18.0	40.0	Load (kN):	19.1	41.4			
Radius (mon.)	Displaceme	nt (mma)	Radius (mma)	Displaceme	ent (mana)	Radius (mma)	Displace	ment (mm)			
					<del></del> -						
140	0.1087	0.1715	140	0.685	1.320	140	0.4762	0.9832			
298	0.0077	0.0148	286	0.363	0.696	289	0.2159	0.4902			
378	0.0049	0.0125	381	0.186	0.414	369	0.1032	0.2723			
457	0.0030	0.009	470	0.114	0.238	460	0.0679	U.1470			
768	0.0026	0.0105	756	0.036	0.069						
6 March 1979	9 (Day 65)		3 April 1979	(Day 93)		24 July 1979	(Day 206)				
Load (kN):	18.7	38.7	Load (kN):	18.7	41.1	Load (kN):	20.5	43.1			
Radius (mm)	Displaceme		Radius (mma)	Displaceme		Radius (mm)		ment (mm)			
-											
133	1.6178	2.3425	136	0.5986	1.1698	140	0.5178	1.0145			
286	0.9290	1.2258	279	0.2921	0.6883	279	0.1372	0.2946			
372	0.5894	0.5617	359	0.1935	0.4581	387	0.0735	0.1613			
454	0.3180	0.2770	451	0.1123	0.2759	473	0.0527	0.1165			
746	0.1936	0.3663	749	0.0327	0.0676	765	0.0214	0.0372			
12 March 197	79 (Day 71)		23 April 1979	(Dav 113)		27 September	1979 (Dav	270)			
Load (kN):	19.6	38.9	Load (kN):	18.9	39.4	Load (kN):	20.7	43.6			
Radius (mma)	Displaceme		Radius (mm)	Displaceme		Radius (mm)	Displace	ment (mm)			
				-		-					
1.40	• •••										
140	0.824	1.587	143	0.5987	1.2120	140	0.5145	1.0755			
292	0.813	1.461	298	0.1829	0.4394	283	0.1803	0.4039			
292 378	0.813 0.242	1.461 0.413	298 390	0.1829 0.0980	0.4394 0.2335	283 365	0.1803 0.6877	0.4039 0.2387			
292 378 467	0.813 0.242 0.128	1.461 0.413 0.270	298 390 476	0.1829 0.0980 0.0585	0.4394 0.2335 0.1414	283 365 454	0.1803 0.6877 0.0416	0.4039 0.2387 0.1260			
292 378	0.813 0.242	1.461 0.413	298 390	0.1829 0.0980	0.4394 0.2335	283 365	0.1803 0.6877	0.4039 0.2387			

# Pavement and Subgrade Temperatures (°C)

Depth (mm)	30 Oct	12 Feb	6 Mar	12 Mar	20 Mar	27 Mar	3 Apr	23 Apr	8 May	30 May	24 July	27 Sep	19 Nov
Surface	12.5	3.7	8.4	10.5		15.1	8.3		23.5		39.6		
50		-2.6	5.4	6.6	9.5	1.3	7.8	18.3	18.7	15.7			
230		-8.5	2.4	0.2		2.1	2.8	18.9	18.0	19.1	31.3		
330		-7.1	0.5	0.3	0.1	3.2	3.1	14.5	18.3	19.4	29.0		
410		-5.7	0.1	0.2	0.1	3.8	3.5	12.3	17.8	19.1	28.1		
520		-4.2	-0.1	0.2	90.4	4.1	3.6	10.4	16.9	18.4	27.4		
600		-3.3	-0.1	0.2	0.8	4.2	3.7	9.7	16.2	18.0	26.0		
680		-2.6	-0.1	0.1	1.2	4.2	3.7	9.2	15.5	17.4	25.7		
830		-1.5	-0.1	0.0	1.6	4.2	3.8	8.4	14.3	15.6	22.9		
1090		0.0	0.0	0.1	2.2	4.7	4.1	7.1	12.5	15.2	24.4		
1330		0.7	0.3	0.3	4.0		5.1	6.1	11.2	14.9	20.9		
												~-	

Depth (mm)	12 Feb	6-Mar	12 Mar	20 Mar	7 Mar	3 Apr	23 Apr	8 May	30 May	24 July	27 Sep	19 Nov
152	7.4	0	24.5	4.4	5.8		7.3	9.3	5.4	12.0	4.5	
305	86.2	0	0	3.9	4.9		6.4	7.3	6.8	0	4.5	
559						3.9						
610	1.0	6.8	0	0.5(leak	2.9		6.8	3.4	2.9	6.0	4.0	
711						8.3						
914	1.0	49.0	7.8	5.4	4.9		6.4	5.8	5.4	8.0	6.5	

Table A7. Data from falling-weight deflectometer tests, Ikalanian sand test section.

25 February 1980 (I			12 March 1980 (I		200	19 March 1980 (D		100
Drop Height (mm):	40	219	Drop Height (mm)		200	Drop Height (mm)		
Pressure (kPa):	275	583	Pressure (kPa):	237	544	Pressure (kPa):	273	363
Radius (mm.) Dia	splacement	t (µnna)	Radius (mm)	Displacem	ent (µm)	Radius (mm)	Displace	ment (µm)
0	167	425	0	311	1524	0	795	1146
200	151	414	300	285	1026	300	420	606
400	106	275	525	178	479	525	233	339
800	50	135	750	129	261	750	144	202
1500	21	52	1050	73	144	1050	76	105
22 March 1980 (Day	82)		26 March 1980 (I	Day 86)		29 March 1980 (I	ay 89)	
Drop Height (mm):	50	100	Drop Height (mm)		100	Drop Height (mm)	: 50	100
Pressure (kPa):	207	319	Pressure (kPa):	253	358	Pressure (kPa):	253	350
	splacemen	t (una)	Radius (mm)	Displace	ment (µm)	Radius (mms)	Displace	ment (µm.)
0	593	1151	0	770	1156	0	738	1069
300	467	736	300	415	594	300	413	582
525	273	401	525	244	344	525	203	287
750	155	217	750	156	227	750	127	178
1050	89	121	1050	84	119	1050	78	108
1030	0,							
3 April 1980 (Day	94)		10 April 1980 (I	Day 101)		17 April 1980 (I	ay 108)	
Drop Height (mm):	50	100	Drop Height (mm)	): 50	100	Drop Height (mm)	: 50	100
Pressure (kPa):	248	355	Pressure (kPa):	230	332	Pressure (kPa):	270	370
	splacemen	t (uma)	Radius (mm.)	Displace	ment (μm)	Radius (mm)	Displac	ement (µm)
100100 ()		- <del>V- Z</del>						
0	834	1229	0	784	1121	0	842	1189
300	441	635	300	416	592	300	447	659
525	198	281	525	224	319	525	199	277
750	119	173	750	126	181	750	122	171
1050	71	102	1050	80	111	1050	74	102
1030	/ 1	102	1050					

#### Pavement and Subgrade Temperature (°C)

Depth (mmn)	25 Feb	12 Mar	22 Mar	26 Mar
Surface	11.3	14.3	4.4	13.1
50	8.0	11.7	4.4	12.7
210	-0.6	0.0	0.9	3.6
340	-0.6	-0.1	1.4	3.7
410	-0.4	0.0	1.4	3.7
450	-0.3	0.3	1.6	3.7
610	-0.2	0.8	1.6	3.4
690	0.3	1.1	1.5	3.2
840	1.2	1.8	1.6	2.8
1060	1.8	2.6	2.0	2.6
1260	2,7	3.3	2.4	2.6
1460	3.7	4.4	3.3	3.1

Moisture Tension

No data

Table A8. Data from falling-weight deflectometer tests, Graves sand test section.

12 March 1980 (D	ay 72)		19 March 1980	(Day 79)	
Drop Height (mm)	: 50	200	Drop Height (n	um.): 50	
Pressure (kPa):	250	550	Pressure (kPa)	267	
Radius (mm)	Displacement	(μm.)	Radius (mm)	Displacement	(man)
0	392	1411	0	1054	
300	388	940	300	522	
525	189	446	525	217	
750	116	230	750	110	
1050	61	116	1050	67	
26 March 1980 (D	ay 86)		29 March 1980	(Day 89)	
Drop Height (mm)	: 50		Drop Height (n	man): 25	50
Pressure (kPa):	238		Pressure (kPa)	): 159	240
Radius (mm)	Displacement	(pm)	Radius (mm)	Displacement	(pm)

22 March 1980 (Day 82) Drop Height (mm): 50 Pressure (kPa): 185 Radius (mm) Displaceme	ent (µma)	26 March 1980 ( Drop Height (mm Pressure (kPa): Radius (mm)	): 50	(µma)	29 March 1980 (Day 89) Drop Height (mm): 25 Pressure (kPa): 159 Radius (mm) Displacement	50 240 (µm)
0 942		0	1308		0 551	989
300 581		300	522		300 341	547
525 304		525	263		525 174	260
750 139		750	146		750 95	134
1050 88		1050	75		1050 54	73
3 April 1980 (Day 94)		10 April 1980 (	Day 101)		17 April 1980 (Day 108)	
Drop Height (mm): 25	50	Drop Height (mm	): 50	100	Drop Height (mm): 50	100
Pressure (kPa): 200	255	Pressure (kPa):	235	334	Pressure (kPa): 230	322
Radius (mm) Displaceme	ent (µma)	Radius (mm)	Displacement	(µma)	Radius (mm) Displacement	(hm)
9 774	1013	0	972	1352	0 940	1335
300 362	461	300	579	845	300 538	792
525 162	208	525	287	409	525 247	357
750 98	123	750	110	169	750 106	143
1050 65	80	1050	70	98	1050 72	96

25 February 1980 (Day 56) Drop Height (mm): 36 Pressure (kPa): 261 Radius (mm) Displacem

400

Displacement

566 (µman)

345 211

Pavement and Subgrade Temperatures (°C)										
Depth (mon.)	25 Feb	12 Mar	19 Mar	26 Mar	29 Mar	3 Apr	10 Apr	<u>17 Apr</u>		
Surface	-0.6	11.8	18.2	13.7	11.3	18.9	13.6	15.8		
51	0.1	2.1	1.7	4.9	8.1	10.5	10.7	12.9		
152	-0.3	0.0	-0.1	2.1	6.6	4.2	8.6	7.1		
305	-0.1	-0.1	-0.2	1.4	5.7	3.4	7.1	7.1		
457	0.3	0.2	0.1	1.2	4.2	3.8	6.2	8.2		
610	0.8	0.6	0.4	1.3	3.3	3.7	5.6	8.0		
762	1.3	1.1	0.8	1.1	2.3	3.1	4.8	7.3		
914	1.8	1.6	1.2	1.2	2.0	2.8	4.4	6.6		
1067	2.3	1.9	1.6	1.4	1.9	2.6	4.0	6.1		
1219	2.8	2.4	2.0	1.6	2.0	2.4	3.7	5.4		
1371	3.2	2.8	2.3	1.9	2.1	2.4	3.5	5.1		
1524	3.5	3.0	2.5	.2.1	2.3	2.4	3.4	4.9		

	Moisture Tension (kPa)											
Depth (mm)	25 Feb	12 Mar	<u>19 Mar</u>	22 Mar	26 Mar	29 Mar	3 Apr	10 Apr	17 Apr			
152	3.0	0	0	0	5.0	6.0	7.0	4.0	10.0			
305	16.5	0.5	2.0	0	7.0	7.0	8.0	5.5	10.0			
610	11.5	9.0	7.0	5.0	5.0	7.0	7.5	4.0	8.0			
914	2.0	0	0	0	0	0	0.5	0	0			

Table A9. Data from falling-weight deflectometer tests, Hart Brothers sand test section.

			m		1 -
Kesillent	Displacement	aι	TWO	LOMG	revers

25 February 19	80 (Day 56	)	12 March 1980 (Da			19 March 1980 (Da		
Drop Height (m	<u>m): 36</u>	200	Drop Height (mm)		200	Drop Height (mmn)		100
Pressure (kPa)	: 279	605	Pressure (kPa):	255	599	Pressure (kPa):	266	382
Radius (mm)	Displace	ment (µm)	Radius (mm.)	Displac	ement (µm)	Radius (mma)	Displac	ement (µm)
0	74	197	0	273	1039	0	696	1115
200	67	169	300	146	358	300	322	467
400	29	84	600	79	149	525	129	176
800	16	47	1050	34	73	750	77	106
1500	11	26	1350	27	55	1050	56	77
22 March 1980	(Day 82)		26 March 1980 (Da	av 86)		29 March 1980 (Da	ay 89)	
Drop Height (m		100	Drop Height (mm)		150	Drop Height (mm)	: 50	100
Pressure (kPa)		352	Pressure (kPa):	240	414	Pressure (kPa):	262	360
Radius (mm)		ment (µm)	Radius (mm)	Displac	ement (µm)	Radius (man)	Displac	ement (µm)
KGG TGG (MAI)	DIOPIGE							
0	395	1035	0	805	1 384	0	832	1133
300	341	605	300	386	183	300	492	635
525	186	273	525	188	100	525	189	262
750	116	154	750	110	184	750	110	153
1050	66	89	1050	61	97	1050	65	87
3 April 1980	(Dav 94)		10 April 1980 (Da	av 101)		17 April 1980 (Da	ay 108)	
Drop Height (m		100	Drop Height (mm)		100	Drop Height (mm)	: 50	100
Pressure (kPa)		351	Pressure (kPa):	247	354	Pressure (kPa):	238	331
Radius (mm)		ment (µm)	Radius (mmn)	Displace	ment (µm)	Radius (man)	Displac	ement (µm)
<u> </u>	2.57.2.2.2	<u> </u>						
0	785	1075	0	823	1130	0	803	1086
300	409	564	300	446	599	300	414	563
525	168	237	525	178	250	525	176	240
750	97	139	750	105	147	750	100	140
1050	57	80	1050	63	88	1050	61	82

# Pavement and Subgrade Temperature (°C)

Depth (mma)	25 Feb	12 Mar	19 Mar	26 Mar	29 Mar	3 Apr	10 Apr	<u>17 Apr</u>
Surface	0.3	14.3	16.8	11.3	9.0	12.2	13.2	16.8
51	0.4	1.1	4.5	6.7	7.9	11.1	10.8	12.5
152	-0.6	0.0	0.1	3.0	6.4	4.3	8.8	6.9
305	-0.5	0.0	-0.1	1.4	4.8	2.4	7.7	6.1
457	-0.2	0.0	-0.1	1.2	4.4	3.2	6.7	7.7
610	-0.2	-0.1	-0.1	0.5	3.1	3.3	5.9	8.3
762	0.0	0.0	-0.1	-0.1	2.1	2.9	5.3	8.1
914	0.3	0.2	0.1	0.1	1.3	2.5	4.7	7.6
1067	0.7	0.6	0.4	0.4	1.1	2.2	4.2	7.1
1219	1.1	0.9	0.7	0.7	1.1	1.9	3.8	6.5
1371	1.5	1.3	0.9	0.9	1.2	1.7	3.4	6.0
1524	1.8	1.6	1.3	1.1	1.3	1.6	3.1	5.7

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Depth (mm)	25 Feb	12 Mar	19 Mar	22 Mar	26 Mar	29 Mar	3 Apr	10 Apr	<u>17 Apr</u>
152			0	0	0	0	0	0	1.0
305		2.0	6.0	5.0	8.0	9.0	10.0		9.0
610		0.5	2.0	2.0			4.0		
914	1.0	0	2.0	1.0	1.0	2.0	1.5	0	

Table A10. Data from falling-weight deflectometer tests, Hyannis sand test section.

25 February 198	0 (Day 56)		12 March 1980 (	(Day 72)		19 March 1980 (	Day 79)	
Drop Height (mm	i): 40	219	Drop Height (me	a); 50	200	Drop Height (mm		200
Pressure (kPa):		550	Pressure (kPa):	240	560	Pressure (kPa):	397	552
Radius (mm)	Displacement	(μ <b>m</b> )	Radius (mma)	Displacement	(µmm)	Radius (mm)	Displacement	(hma)
0	99	237	0	76	669	0	566	842
200	57	153	300	67	373	300	273	376
400	35	94	525	50	203	525	148	216
800	18	50	750	51	114	750	91	131
1500	11	25	1050	38	69	1050	56	78
22 March 1980 (	Day 82)		26 March 1980	(Day 86)		29 March 1980 (	Day 89)	
Drop Height (mm		200	Drop Height (me		200	Drop Height (mm	i): 50	200
Pressure (kPa):		516	Pressure (kPa):		487	Pressure (kPa):	255	499
Radius (mma)	Displacement	(բ <b>ա</b> ն)	Radius (mm)	Displacement	(μ <b>m</b> )	Radius (mmm)	Displacement	(µma)
0	194	994	0	439	1004	0	491	1061
300	176	646	300	249	556	300	315	658
525	122	414	525	162	343	525	186	395
750	109	271	750	104	226	750	110	232
1050	75	142	1050	54	115	1050	58	117
3 April 1980 (	Day 94)		10 April 1980	(Day 101)		17 April 1980 (	Day 108)	
Drop Height (me		200	Drop Height (m		200	Drop Height (mm		200
Pressure (kPs):		466	Pressure (kPa)		475	Pressure (kPa):		439
Radius (mm)	Displacement	(µma)	Radius (mm)	Displacement	(µ <b>m</b> )	Radius (mm)	Displacement	(µma)
0	536	1164	0	579	1183	0	562	1139
300	336	714	300	344	692	300	332	705
525	182	390	525	205	429	525	191	407
750	109	230	750	127	265	750	111	230
1050	58	114	1050	69	138	1050	64	123

# Pavement and Subgrade Temperature (°C)

Depth (mma)	25 Feb	12 Mar	19 Mar	26 Mar	29 Mar	<u>03 Apr</u>	10 Apr	17 Apr
Surface	7.9	6.4	11.7	11.4	11.8	24.4	13.3	28.6
51	6.1	4.8	12.1	10.1	10.8	19.9	12.5	26.7
152			2.7	5.2	8.4			16.8
305	0.0	-0.3	1.8	2.2	5.1	5.2	7.9	9.9
457	0.3	-0.4	0.1	0.4	2.6	1.9	6.2	7.4
610	0.1	-0.4	-0.1	-0.1	0,2	1.4	5.1	7.4
762	0.3	-0.4	0.0	0.1	0.1	1.0	4.3	7.3
914	0.6	0.1	0.3	0.3	0.3	0.7	3.7	6.7
1067	0.9		0.6	0.4	0.6	0.7	3.3	5.8
1219	1.3		0.9	0.7	0.8	0.7	2.9	5.5
1371	1.6		1.1	1.0	1.1	0.8	2.7	5.1
1524	2.1		1.4	1.2	1.3	1.0	2.5	4.6

Moisture Tension

No data

Table A11. Data from falling-weight deflectometer tests, dense-graded stone test section.

25 February 19	80 (Day 56)		12 March 1980	(Day 72)		19 March 1980 (	Day 79)	
Drop Height (m		200	Drop Height (m		200	Drop Height (m	): 100	200
Pressure (kPa)		569	Pressure (kPa)		525	Pressure (kPa):	369	508
Radius (mma)	Displacement	(µma)_	Radius (mma)	Displacement	(μ <b>m</b> .)	Radius (==)	Displacement	(har)
0	122	232	0	212	731	0	557	787
200	76	151	300	158	451	300	329	482
400	31	68	525	96	255	525	187	268
800	8	24	750	63	136	750	108	154
1500	7	16	1050	35	64	1050	51	72
22 March 1980	(Day 82)		26 March 1980	(Day 86)		29 March 1980	(Day 89)	
Drop Height (m		200	Drop Height (m	ma): 50	200	Drop Height (m	a): 50	200
Pressure (kPa)		499	Pressure (kPa)		465	Pressure (kPa)	255	470
Radius (mma)	Displacement	(µm)	Radius (mm)	Displacement	(may)	Radius (mm)	Displacement	(µm)
0	123	658	0	324	675	0	338	646
300	153	487	300	215	440	300	237	461
525	127	325	525	129	258	525	139	263
750	96	203	750	79	163	7 50	77	159
1050	60	109	1050	41	83	1050	41	84
3 April 1980	(Day 94)		19 April 1980	(Day 101)		17 April 1980	(Day 108)	
Drop Height (m		200	Drop Height (m		200	Drop Height (m	m): 50	200
Pressure (kPa)		484	Pressure (kPa)		491	Pressure (kPa)	239	451
Radius (mm)	Displacement	(µ <b>za</b> )	Radius (mm)	Displacement	(μ <b>m</b> )	Radius (mm)	Displacement	(µm)
0	413	774	0	362	713	0	411	748
300	254	461	300	233	472	300	260	467
525	127	246	525	141	283	525	136	253
750	68	133	750	80	162	750	67	137
1050	40	75	1050	43	84	1050	39	76

# Pavement and Subgrade Temperature (°C)

Depth (mm)	25 Feb	12 Mar	19 Mar	26 Mar	29 Mar	03 Apr	10 Apr	17 Apr
Surface	12.7	13.8	21.9	11.6	11.3	31.7	13.6	26.7
51	9.9	11.7	19.7	11.0	11.6	26.6	13.2	25.2
152								
305	-0,2	-0.2	1.5	3.4	7.1	5.4	8.1	7.6
457	-0.1	- 0. 1	0.1	2.4	5.8	4.0	6.8	7.4
610	-0.1	-0.2	-0.1	1.8	4.6	3.9	5.9	7.7
762	-0.1	-0.1	-0.2	0.1	3.3	3.4	5.2	7.1
914	0.1	-0.1	0.0	0.4	2.3	2.9	4.5	6.5
1067	0.4	0.3	0.3	0.7	1.7	2.4	3.8	5.8
1219	0.8	0.7	0.8	0.9	1.5	2.0	3.3	5.0
1371	1.2	0.4	1.1	1.3	1.6	1.8	3.0	4.4
1524	1.4	0.9	1.3	1.4	1.7	1.8	2.7	4.1

Depth (==)	25 Feb	12 Mar	19 Mar	22 Mar	26 Mar	29 Mar	03 Apr	10 Apr	17 Apr
559		5.0	0.5	4.0	5.0	5.0	5.0	5.0	5.0
711		0	6.5	10.0	11.0	12.0	11.0	8.5	10.0

Table A12. Data from falling-weight deflectometer tests, Sibley till test section.

Resilient Di	splacement at	Two Load Leve	21s

25 February 1980 (Day	56)	12 March 198	O (Dev 72)		19 March 1980 (Day 79)	
Drop Height (mm):	36 175	Drop Height		200	Drop Height (mm): 50	100
	00 575			600	Pressure (kPa): 254	360
	acement (µm)		Displacement	(pm)	Radius (mm) Displacement	(µma)
			950		0 1005	1371
0	26 69	0	850	1700	The state of the s	632
200	18 48	300	369	766		
400	14 32	525	131	286	525 188	253
800	8 21	750	34	53	750 63	84
1500	6 14	1050	18	30	1050 25	33
22 March 1980 (Day 82	2)	26 March 198	0 (Day 86)		29 March 1980 (Day 89)	
Drop Height (mm):	50 100	Drop Height			Drop Height (mm): 50	200
	67 330				Pressure (kPa): 258	505
	acement (µm.)		Displacement	(µm)	Radius (mm) Displacement	(har)
0 3	61 1310	0	759		0 664	1302
300	44 725		358		300 392	795
	43 355		172		525 147	311
750	99 139		88		750 65	143
1050	48 53		37		1050 37	74
0 4 11 1000 (D 0)		10 April 198	0 (Day 101)		17 April 1980 (Day 108)	
3 April 1980 (Day 94				200	Drop Height (mm): 50	200
Drop Height (mm):			<b>,,</b>	504	Pressure (kPa): 240	455
	65 516		Displacement		Radius (mm) Displacement	(µm)
Radius (mm) Disp!	.acemsent (μm.)	Radius (mm)	Dishracement	(har)	Madida (mm) Dispiacement	
0	89 1460	0	642	1237	0 624	1144
300	38 666	300	343	715	300 323	631
	.14 245	525	113	251	525 122	246
750	50 107	750	57	124	750 49	105
1050	34 69		32	63	1050 33	67

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# Pavement and Subgrade Temperatures (°C)

Depth (mm)	25 Feb	12 Mar	22 Mar	26 Mar
Surface	3.6	17.0	4.4	14.0
50	2.8	14.6	4.5	11.0
230	-0.7	1.0	1.4	3.3
330	-0.6	0.6	1.5	3.1
410	-0.3	0.2	1.4	3.0
520	-0.3	0.1	1.0	2.8
600	-0.3	0.1	0.8	2.7
680	-0.6	0.1	0.5	2.5
830	-0.1	0.2	0.2	2.2
1090	0.9	0.2	0.5	1.6
1030	0.3	0.2	0.8	1.4

Depth (mm)	25 Feb	12 Mar	19 Mar	22 Mar	26 Mar	29 Mar	3 Apr	10 Apr	17 Apr
152	0	0	0	0	0	0	1.0	0	6.0
305	1.0	0	0	0	0	0	0	0	Ó
610	0	0.5	0	0	0	Ó	0	0	Ö
914	3.0	2.5	2.0	0	0	1.0	1.5	1.0	2.0

# APPENDIX B: GROUND TEMPERATURES PREVAILING DURING PLATE-LOADING TESTS

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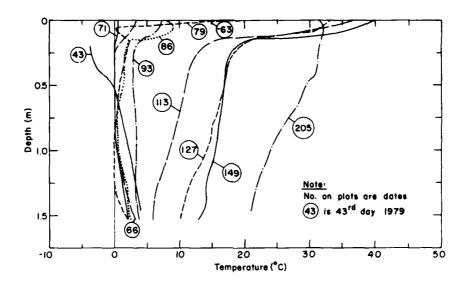


Figure B1. Ikalanian sand, 1979.

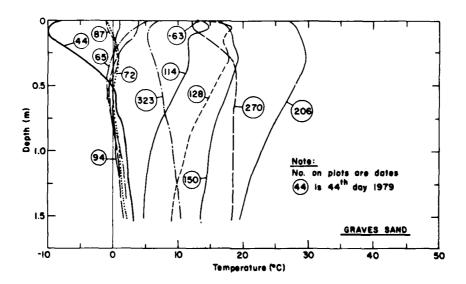


Figure B2. Graves sand, 1979.

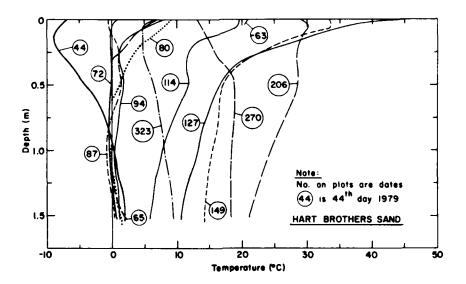


Figure B3. Hart Brothers sand, 1979.

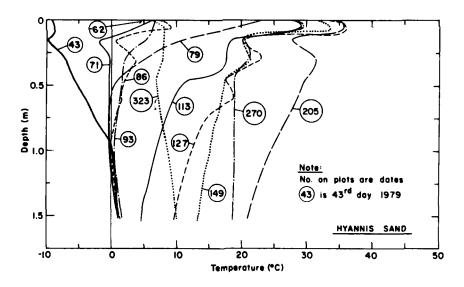
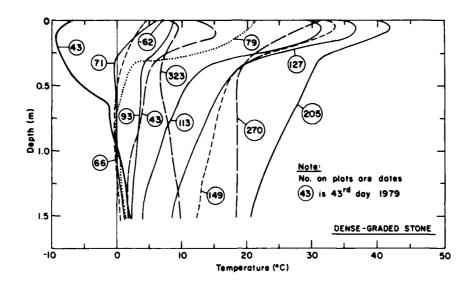


Figure B4. Hyannis sand, 1979.



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Figure B5. Dense-graded stone, 1979.

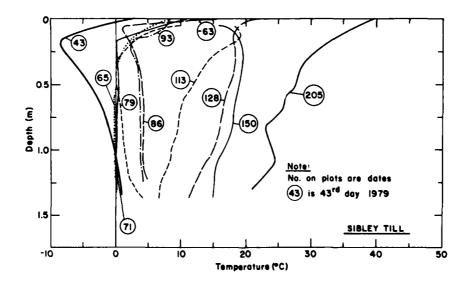


Figure B6. Sibley till, 1979.

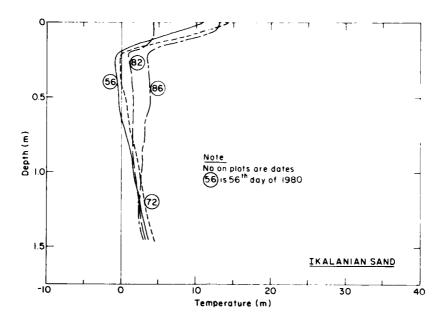


Figure B7. Ikalanian sand, 1980.

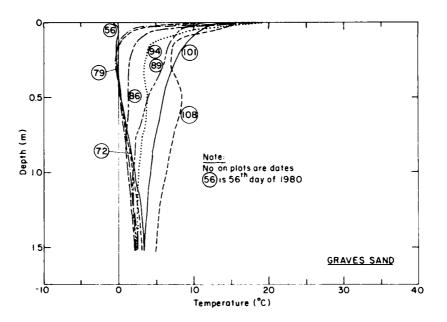


Figure B8. Graves sand, 1980.

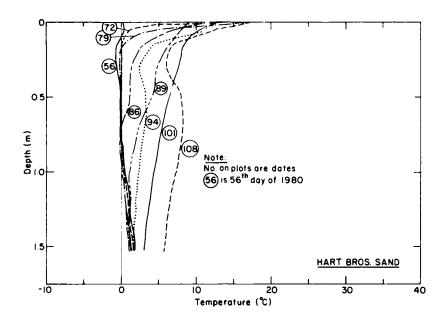


Figure B9. Hart Brothers sand, 1980.

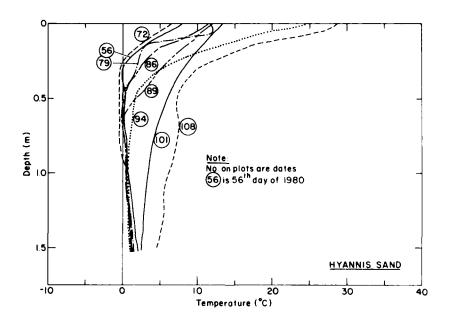


Figure B10. Hyannis sand, 1980.

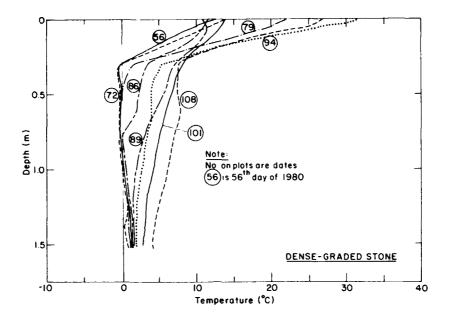
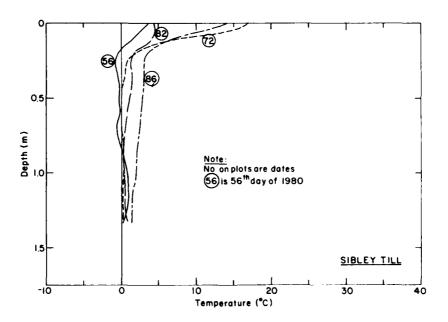


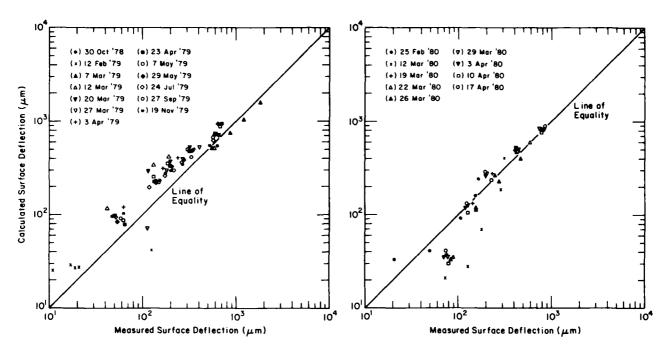
Figure B11. Dense-graded stone, 1980.



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Figure B12. Sibley till, 1980.

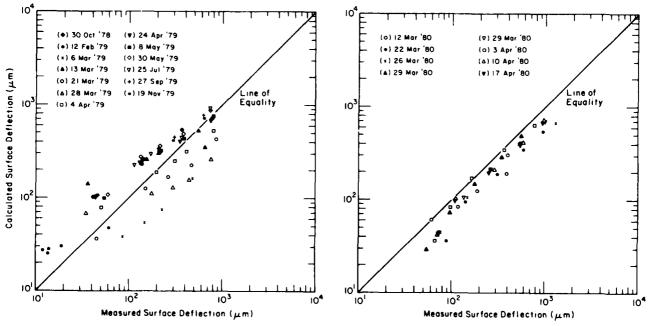
# APPENDIX C: MEASURED SURFACE DEFLECTIONS COMPARED WITH DEFLECTIONS CALCULATED BY NELAPAV (Lower of two levels of applied plate pressure)



a. 1979 RPB tests at 243-283 kPa plate pressure.

b. 1980 FWD tests at 207-275 kPa plate pressure.

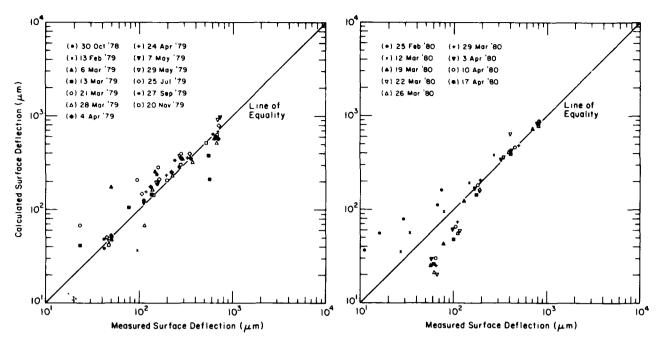
Figure C1. Measured surface deflections compared with deflections calculated by NELAPAV, Ikalanian sand test section.



a. 1979 RPB tests at 101-298 kPa plate pressure.

b. 1980 FWD tests at 159-250 kPa plate pressure.

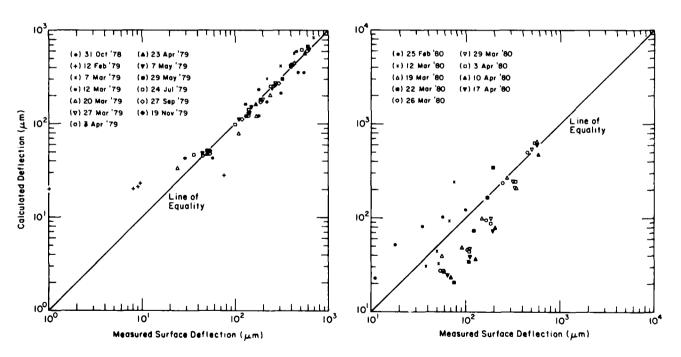
Figure C2. Measured surface deflections compared with deflections calculated by NELAPAV, Graves sand test section.



a. 1979 RPB tests at 245-285 kPa plate pressure.

b. 1980 FWD tests at 195-265 kPa plate pressure.

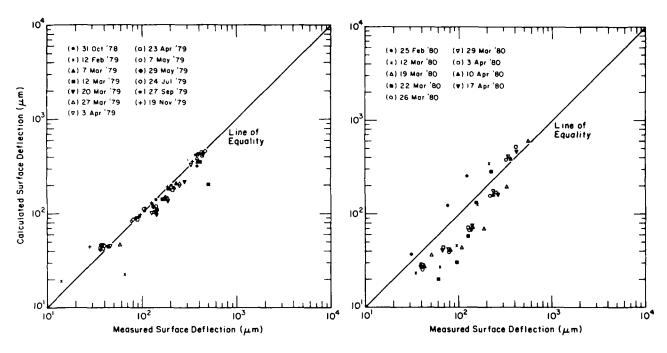
Figure C3. Measured surface deflections compared with deflections calculated by NELAPAV, Hart Brothers sand test section.



a. 1979 RPB tests at 215-283 kPa plate pressure.

b. 1980 FWD tests at 196-397 kPa plate pressure.

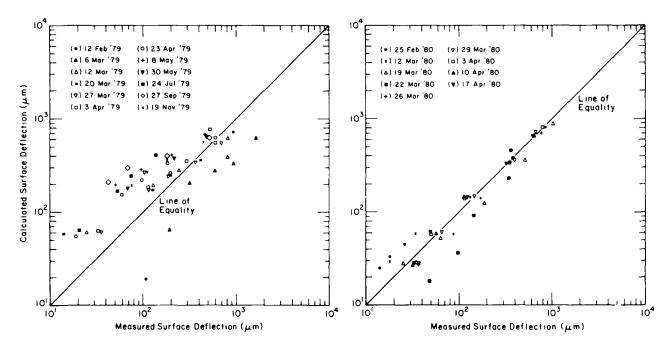
Figure C4. Measured surface deflections compared with deflections calculated by NELAPAV, Hyannis sand test section.



a. 1979 RPB tests at 249-274 kPa plate pressure.

b. 1980 FWD tests at 201-369 kPa plate pressure.

Figure C5. Measured surface deflections compared with deflections calculated by NELAPAV, dense-graded stone test section.



a. 1979 RPB tests at 246-281 kPa plate pressure.

b. 1980 FWD tests at 167-300 kPa plate pressure.

Figure C6. Measured surface deflections compared with deflections calculated by NELAPAV, Sibley till test section.

# APPENDIX D: RESILIENT MODULI AND SUPPORTING DATA CALCULATED BY NELAPAV Table D1a. Resilient moduli and supporting data calculated by NELAPAV for Ikalanian test section, 1979.

30 October 1978 (Daym63) Plate Pressure (kPa):	258.7	517.4		23 April 1979 (Day 113) Plate Pressure (kPa):	253	539	,
Thickness	H <sub>r</sub> J <sub>i</sub> (NPa) (NPa)	π <sub>ε</sub> J <sub>l</sub> φ γ	ld j Fr	Thickness (m) Materials	M <sub>r</sub> J <sub>1</sub>	H <sub>e</sub> J	T(*C)  or  ** Yd **r  ((n)) (***/3)
(m) Materials  0.050 Asphalt Concrete 0.250 1.5. (thawed) 0.350 1.3. (thawed) 0.874 1.S. (thawed) 1.524 Subgrade  — Subgrade	78.0 -92.83 51.3 -39.33 33.1 -60.39 177.0 -66.88 200.0	3412.0 15.2° 2 105.7 -171.60 10.0 kPa i 58.1 - 50.63 10.0 kPa i 34.8 - 66.98 5.0 kPa i 180.8 - 68.89 1	.656 .35	(m) Materials  0.050 Asphalt Concrete 0.250 1.5. (thawed) 0.350 1.5. (thawed) 0.874 1.5. (thawed) 1.524 Subgrade - Subgrade	450.0 49.3 -136.60 32.6 -50.55 33.1 - 60.45 175.6 - 66.10 200.0	(MPa) (kPa)  450.0 69.9 -277.10 39.7 - 75.72 35.4 - 69.37 179.9 - 68.39 200.0	(kpa) (Hg/m <sup>2</sup> )  35* 2.320 .40 5 kPa 1.590 .40 7 kPa 1.590 .40 5 kPa 1.590 .40 1.055 .35 1.055 .35
12 February 1979 (Day 43) Plate Pressure (kPa):	249.0	573.0 T(*c)		7 May 1979 (Day 127) Plate Pressure (kPe):	264	547	T(*C)
Thickness (m) Hateriels	H J c (MPa) (kPa)		(d 3) Pr	Thickness Materials	K <sub>r</sub> J <sub>1</sub> (MPa) (kPa)	M <sub>C</sub> J <sub>1</sub> (MPa) (MPa)	or Yd Hr (kPa) (Hg/m)
0.050 Asphalt Concrete 0.250 I.S. (frozen) 0.350 I.S. (frozen) 0.874 I.S. (thawed) 1.524 Subgrade Subgrade	15705.0 8398.1 Toct=52.18 7141.5 Toct=18.77 78.0 22.39 172.3 -64.37 200.0	6090.4 Toct=120.99 -3.5° I 5296.1 Toct=410.62 -2.4° I 39.1 - 55.55 7.0 kPa I 175.8 - 66.26 I	2.320 .30 1.444 .35 1.504 .35 1.609 .40 1.055 .35	0.050 Asphalt Concrete 0.250 1.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade - Subgrade	556.3 54.0 ~132.30 30.5 ~51.11 33.2 ~60.74 175.8 ~66.19 200.0	\$56.3 75.3 -260.80 37.0 - 75.64 35.5 - 69.50 180.0 - 68.46 200.0	33" 2.320 .40 8 kPa 1.590 .40 5 kPa 1.590 .40 5 kPa 1.590 .40
7 March 1979 (Day 66) Plate Pressure (kPa):	264	532		29 May 1979 (Day 149)	24.1	***	
Thickness	H <sub>e</sub> J <sub>1</sub>	τ(*c)	<sup>Y</sup> d , <sup>μ</sup> ε	Place Pressure (kPa): Thickness	H <sub>r</sub> J <sub>1</sub>	552 M <sub>r</sub> J <sub>1</sub>	T(*C)
(m) Haterials 0.050 Amphalt Concrete	(MPa) (kPa)	(MPa) (kPa) (kPa) (M	g/m <sup>3</sup> ) 320 .40	(m) Materials  0.050 Asphalt Concrete	(MPa) (kPa) 295.1	(HDPa) (kPa)	(kPa) (Mg/m³)
0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade  w Subgrade	12.2 -107.90 14.6 - 59.63 25.2 - 61.35 173.1 - 64.76 200.0	17.3 -219.60 0 kPs 1.4 18.4 - 95.52 0 kPs 1.4 27.7 - 72.61 0 kPs 1.5 179.3 - 68.09 1.6 1.6	504 .45	0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade Subgrade	55.8 ~141.50 30.7 ~ 51.76 33.2 ~ 60.82 175.7 ~ 66.17 200.0	78.8 ~285.90 37.6 ~ 78.14 35.6 ~ 70.06 180.1 ~ 68.51 200.0	
12 March 1979 (Day 71) Place Pressure (kPa):	28 i	545		24 July 1979 (Day 206) Plate Pressure (kPs):	271	552	
Thickness (m) Haterials	H J r (MPa) (kPa)	T(*C)  Hr J OF  (MPa) (kPa) (kpa) (Hg	γ <sub>d</sub> μ <sub>r</sub>	Thickness (m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa)	Hr J (MPa) (kPa)	T(°C)  or  **  **  (kPa) (Mg/m²)
0.050 Aaphalt Concrete 0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade  ** Subgrade		10000.0 0.5° 2.1 46.4 -171.10 0 kPa 1.5	320 .35 590 .45 590 .45 590 .40 555 .35	0.050 Asphalt Concrete 0.250 I.S. (thewed) 0.350 I.S. (thewed) 0.874 I.S. (thewed) 1.524 Subgrade  Subgrade	700.0 91.6 -128.30 54.6 - 41.51 33.4 - 61.47 174.8 - 66.48 200.0	700.0 126.1 -246.30 63.0 - 55.42 35.5 - 69.53 179.3 - 68.71 200.0	32° 2.320 .40 10 kPa 1.656 .35 11 kPa 1.656 .35 5 kPa 1.590 .40
20 March 1979 (Day 79)	200.0	200.0 55 1.6		27 September 1979 (Day 270)		200.0	1.033 .33
Plate Pressure (kPa):	256	535 T(*C)		Plate Pressure (kPa):	274	584	τ(*c)
Thickness (m) Haterials	H <sub>r</sub> J <sub>l</sub> (HPa) (kPa)	H <sub>E</sub> J <sub>L</sub> OT T (MPa) (kPa) (kPa) (My	<sup>1</sup> d <sup>μ</sup> r <sub>2</sub> /m <sup>3</sup> )	Thickness (m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa)	H <sub>r</sub> J <sub>i</sub> (Mra) (kPa)	(kPa) (Mg/m)
0.050 Asphalt Concrete 0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.814 I.S. (thawed) i.524 Subgrade Subgrade 27 March 1979 (Day 86)	5174.0 42.2 - 85.95 29.4 - 47.50 33.4 - 60.31 175.7 - 66.18 200.0	5174.0 10* 2.3 59.1 -171.10 7 kPa 1.5 35.5 - 69.52 5 kPa 1.5 35.2 - 68.59 5 kPa 1.5 180.0 - 68.43 1.0 200.0 1.0	590 .40 590 .40 590 .40 555 .35	0.050 Asphelt Concrete 0.250 L.S. (thewed) 0.350 I.S. (thewed) 0.874 I.S. (thewed) 1.524 Subgrade - Subgrade	978.0 84.0 -107.70 36.0 - 46.88 41.1 - 61.82 175.6 - 66.47 200.0	978.0 118.0 -215.20 43.4 - 68.55 44.1 - 71.23 179.7 - 68.90 200.0	7 kPs 1.609 .40 7 kPs 1.609 .40
Plate Pressure (kPa).	247	548 T(*C)		19 November 1979 (Day 323) Plate Pressure (kPa):	281	591	T(*C)
Thickness(m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa) (kPa)	H J, OT Y	(4 ½r 1/a <sup>3</sup> )	Thickness (m) Materials	H <sub>r</sub> J <sub>i</sub> (MPa) (kPa)	H <sub>r</sub> J <sub>1</sub> (MPa)	or Yd, Wr (kPa) (Ng/m)
0.050 Asphalt Concrete 0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade  Subgrade	38.5 - 82.43 29.2 - 46.86 33.0 - 60.07 175.6 - 66.10 200.0	5600.0 8° 2.3 55.7 -174.60 5 kPa 1.5 35.8 - 70.96 5 kPa 1.5 35.4 - 69.09 5 kPa 1.5 180.2 -68.54 1.0 200.0 1.0	320 .40 990 .40 990 .40 990 .40	0.050 Asphalt Concrete 0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade	5600.0	5600.0	8° 2.320 .40 10 kPa 1.656 .35 10 kPa 1.656 .35 5 kPa 1.590 .40
3 April 1979 (Day 93) Plate Pressure (RPs):	261	T(°c)	<b>W</b>	es: (1) Moduli, stresse	a and strains cal	culared by MELADAY	
Thickness (m) Materials	M J c (MPa) (kPa)	or	d <sup>u</sup> r Va)	(2) M. * remilient	modulus, J. = firs	t atress invarient	
0.050 Asphalt Concrete 0.250 I.S. (thawed) 0.350 I.S. (thawed) 0.874 I.S. (thawed) 1.524 Subgrade - Subgrade	6423.0 41.4 - 82.79 29.4 - 47.46 33.1 - 60.45 175.8 - 66.22 200.0	643.0 7° 2.3 57.4 -160.80 7 kps 1.5 15.2 -68.18 5 kps 1.5 15.2 -68.17 5 kps 1.5 180.2 -68.42 1.0 200.0 1.0	120 .40 190 .40 190 .40 190 .40 155 .35	(3) $H_T$ and $J_1$ are c (4) 1.5. refers to (5) $\tau_{OCL}$ = octahedr	alculated at r=0 a Ikalanian samd (ne al sheer atress (h	and center of respe	ctive layer as noted).
r. (low pressure): 3	30 Oct 12 Feb .154×10 <sup>-4</sup> -1.307×10	Tangential Strain c; (r = 0	Har 27 Har	3 Apr 23 Apr 7	May 29 May	24 Jul 27 Sep 3.833x10 <sup>-4</sup> 4.309x1	
·							
		-6 1.545x10 <sup>-3</sup> 5.124x10 <sup>-4</sup> 6.537					
c <sub>y</sub> (low pressure)1	.921x10 <sup>-4</sup> -1.743x10	-4-1.700x10 <sup>-4</sup> -2.110x10 <sup>-4</sup> -2.021	1x10 <sup>-4</sup> -2.015x10 <sup>-4</sup> -	-2.031×10 <sup>-4</sup> -2.038×10 <sup>-4</sup> -2.06	51x10 <sup>-4</sup> -2.065x10 <sup>-4</sup> -	1.326×10 <sup>-4</sup> -1.352×10	-4 -1.325x10 <sup>-4</sup>
(high pressure). ~2	.405x10 <sup>-4</sup> -1.095x10	-4-2.413x10 <sup>-4</sup> -2.720x10 <sup>-4</sup> -2.631	1×10 <sup>-4</sup> -2.673×10 <sup>-4</sup> -	-2.652×10 <sup>-4</sup> -2.700×10 <sup>-4</sup> -2.70	9x10 <sup>-4</sup> -2.747x10 <sup>-4</sup> -	1.551x10 <sup>-4</sup> -1.571x10	-4 -1.508x10-4

Table D1b. Resilient moduli and supporting data calculated by NELAPAV for Ikalanian test section, 1980.

25 Pebruary 1980 (Day 56	<u>)</u>		29.	March 1980 (Day 88)			
Plate Pressure (kPa):	275	583	Pi	ate Pressire (67)	253	150	re*c)
Thickness (m) Materials	H <sub>r</sub> J <sub>l</sub> (HPa) (HPa)	1( C) H <sub>r</sub> J <sub>1</sub> φ Y <sub>d</sub> μ (MPa) (kPa) (kPa) (Mg/m <sup>3</sup> )		t kness (m) Materials	MPAT APA	MPa CKPA	or d Pr CuPat (Ng/m)
0.050 Asphalt Concret 0.100 I.S. (chawed) 0.500 I.S. (frogen) 0.874 I.S. 1.524 Subgrade Subgrade	9115.0 32.7 -309.20 1956.7 toct=20.44 36.6 - 54.24 171.1 - 64.39 200.0	9115.0 9.6° 2.320 49.2 -711.40 0 kPa 1.504 1432.9 Toct* 46.195° 1.444 38.2 - 59.02 9 kPa 1.590 173.1 - 66.52 1.055	0 0 5 0 15 0	USO   Asphil'   on rete   325   LS   (thaued)   325   LS   (thaued)   824   LS   524   Subgrade   Subgrade	2024 10 36 4 13 5 44 6 44 16 20 6 62 3 111 5 5 5 41 200 0	35 5 97 73 26 4 50 15 26 1 65 42 72 6 6 75	12° 2 320 .45 U kPa t 590 .45 4 kPa 1.590 .40
12 March 1980 (Day 72)			ر ز	Apr. 1 1980 (Day 94)			
Plate Pressure (kPa):	237	T(*C)	Pla	ate Pressure (APA)	248	155	
Thickness (m) Haterials	H <sub>E</sub> J <sub>L</sub> (MPa)	or Y <sub>d</sub> <sup>µ</sup> r (kPa) ( <b>Kg/</b> m <sup>3</sup> )		ickness (m) Materials	M j r i (MPa) (kPa)	H J r (NPa) (kPa)	T(*C) or * * *d * *r (kPa) (Ng/m <sup>3</sup> )
0.050 Amphalt Concrets 0.325 1.S. (thewed) 0.325 L.S. (fromen) 0.874 L.S. 1.52 Subgrade  Subgrade		13" 2.320 .40 2 kPa 1.590 .45 5" 1.504 .35 9 kPa 1.609 .40 1.055 .35 1.055 .35	0. 0. 0.	.050 Asphalt Convrete .325 I 5 (thawed) .325 I 5 (thawed) .324 I 5524 Subgrade e Subgrade	6909.0 35.1 - 72.73 24.7 - 43.45 25.6 - 61.80 171.2 - 65.86 200.0	6090.0 40.9 - 99.65 26.4 - 49.87 26.3 - 35.25 172.8 - 66.72 200.0	18" 2.320 .50 2 kPa 1.590 .45 4 kPa 1.590 .40 0 kPa 1.576 .45 1.055 .35
12 March 1980 (Day 72)			ĨO	April 1980 (Day 101)			
Plate Pressure (kPa):	594	1(,¢)	<b>2</b> 16	ste Pressure (kPa)	230	332	T(*c)
Thickness (m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa)	οτ γ <sub>d</sub> μ <sub>r</sub> (kPa) (Ng/a <sup>3</sup> )		ickness (m) Haterials	H <sub>r</sub> J <sub>i</sub> (MPa) (kPa)	H <sub>r</sub> J <sub>l</sub> (NPa) (NPa)	or + Yd Hr (kPa) (Mg/m <sup>3</sup> )
0.050 Asphalt Concrete 0.325 L.S. (thewed) 0.325 L.S. (thewed) 0.874 L.S. 1.524 Subgrade  Subgrade	6860.0 43.3 -128.60 16.9 -70.34 47.1 -70.19 177.4 -68.19 200.0	13° 2.320 .40 2 kPa 1.390 .45 2 kPa 1.504 .45 9 kPa 1.609 .40 1.055 .35 1.055 .35	0. 0. 0.	.050 Asphalt Concrete .325 L.S. (thawed) .325 L.S. (thawed) .325 L.S. (thawed) .524 L.S524 Subgrade	6090.0 72.44 26.9 - 42.24 25.5 - 61.29 174.9 - 65.73 200.0	6090.0 38.4 - 99.88 28.7 - 48.28 26.1 - 64.71 176.5 - 66.57 200.0	15° 2.320 .40 2 kPa 1.590 .45 4 kPa 1.590 .40 0 kPa 1.576 .45 1.055 .35
19 March 1980 (Day 79)			17	April 1980 (Day 108)			
Plate Pressure (kPa):	273	T(*c)	Pl	ate Pressure (kPa):	270	370	T(*C)
Thickness (m) Materials	H <sub>r</sub> J <sub>i</sub> (MPa) (kPa)	or	r Th	ickness (m) Materials	H <sub>T</sub> J <sub>1</sub> (HPa) (kPa)	<sup>Н</sup> г <sup>Ј</sup> і (н <b>г</b> а) (к <b>г</b> а)	οτ τ γ <sub>d</sub> μ <sub>r</sub> (kPa) (Hg/m <sup>3</sup> )
0.050 Asphalt Concret 0.325 L.S. (chaued) 0.325 L.S. (chaued) 0.824 L.S. 1.524 Subgrade — Subgrade	e 9154.0 31.2 - 75.22 27.2 - 49.25 29.2 - 61.61 171.6 - 66.08 200.0	35.4 - 97.26 0 kPa 1.590 28.9 - 55.95 2 kPa 1.590 29.8 - 64.29 4 kPa 1.576 173.0 - 66.82 1.055	65 0 65 0	.050 Asphalt Concrete .325 I.S. (thawed) .325 I.S. (thawed) .325 I.S. (thawed) .324 I.S524 Subgrade = Subgrade	6090.0 31.9 - 73.65 29.3 - 43.96 27.5 - 62.65 171.6 - 66.06 200.0	6090.0 36.6 - 97.74 31.3 - 49.58 28.2 - 60.01 173.1 - 66.88 200.0	
22 March 1980 (Day 82)							
Plate Pressure (kPa):	207						
Thickness (m) Haterials	H J (MPa) (kPa)	or	r 				
0.050 Asphalt Concret 0.325 I.S. (thawed) 0.325 I.S. (thawed)	26.3 - 53.21 25.0 - 41.88	13440.0 4.4° 2.320 .4 31.5 - 77.00 0 kPa 1.590 .4 27.1 - 49.47 2 kPa 1.590 .4	4 Motes:	(1) Moduli, stresse	es, and strains cale	rulated by NELAPAV	
0.824 I.S. 1.524 Subgrade - Subgrade	25.3 - 60.42 171.1 - 65.54 200.0	26.1 - 64.27 0 kPa 1.576 .4 173.7 - 66.48 1.055 .3 200.0 1.055 .3	<b>)</b>	(2) M <sub>r</sub> = resilient p = moisture te			or bulk stress, ilient Poisson's ratio
26 March 1980 (Day 86)				(3) H <sub>r</sub> and J <sub>1</sub> are o	alculated at r=0 a	nd center of respect	tive layer
Plate Pressure (kPa):	253	358 T(*C)		(4) I.S. refers to	Ikalanian sand (ner	rer fromen except or	, moted).
Thickness	м <sub>г</sub>	, or		(5) took = octahedr	ral shear stress (M	Pa)	
(m) Materials	(HPa) (kPa)	"r 'l ' 'd '' (HPa) (kPa) (kPa) (Hg/m <sup>3</sup> )				ins are compressive.	
0.050 Asphalt Concret	7124.0	7124.0 12.9* 2.320 .4					

#### Tangential Strain $\varepsilon_{c}$ (r = 0, z = .05) and Vertical Strain $\varepsilon_{v}$ (r = 0, z = 1.524)

ε <sub>ξ</sub> (low pressure):		12 Mar 2.422×10 <sup>-4</sup>							
(high pressure):	3.118×10 <sup>-4</sup>	6.476x10 <sup>-4</sup>	3.645×10 <sup>-4</sup>	2.644×10 <sup>-4</sup>	4.304×10 <sup>-4</sup>	4.142x10 <sup>-4</sup>	4.279x10 <sup>-4</sup>	4.325x10 <sup>-4</sup>	4.559x10 <sup>-4</sup>
ε <sub>γ</sub> (1ον pressure):	-1.162×10 <sup>-4</sup>	-1.209×10 <sup>-4</sup> -	1.370×10 <sup>-4</sup> -	1.500x10 <sup>-4</sup> -	1,361x10 <sup>-4</sup> -	1.361×10 <sup>-4</sup> -	1.358x10 <sup>-4</sup> -	1.340x10 <sup>-4</sup> -	l.382×10 <sup>-4</sup>
(hish programme)	-1 251-10-4	-1 562=10 <sup>-4</sup> -	1 441-10-4	1 788-10-4	1 668-10-4	.1 442=10-4	1.445×10 <sup>-4</sup> -	1 424 *10 -4 -	1 452=10-4

Table D2a. Resilient moduli and supporting data calculated by NELAPAV for Graves sand test section, 1979.

Plate Pressure (kPa):	4 April 1979 (Day 94)  Plate Pressure (kPa):  Thickness (a) Materials  0.050 Asphalt Concrete 0.484 G.S. (thawed) 0.198 G.S. (trosen) 0.088 G.S. (thawed) 0.734 G.S. (rec.) 1.524 Subgrade 24 April 1979 (Day 114)  Plate Pressure (kPa):  Thickness (a) Materials  0.050 Asphalt Concrete	46.9 - 67.68 4057.5 toct=13.40 34.9 - 45.53 37.6 - 57.81 165.7 - 62.86 200.0	9391.0 (kFa) 9391.0 (cFa) 62.9 -128.2 2398.6 tact= 29.9 39.1 - 58.1 39.4 - 66.6 169.9 - 65.1 200.0	Τ(*C)  or  ψ (ωpa) (ωpa)  1.0* 2.320 .3  20 7.8 ωpa 1.501 .3
Thickness	Thickness (a) Materials  0.050 Asphalt Concret  0.484 G.S. (thawed)  0.198 G.S. (frozen)  0.058 G.S. (thawed)  0.734 G.S. (rec.)  1.324 Subgrade  24 April 1979 (Day 114)  Plate Pressure (kPa):  Thickness (a) Materials	H <sub>r</sub>   J <sub>1</sub>   (NPa)	H <sub>r</sub> J <sub>1</sub> (NPa) (NPa)  9391.0 62.9 -128.2 2398.6 toct= 23.9 39.1 - 58.1 39.4 - 64.6	or Y <sub>d</sub> µ (kPa) (Ng/m <sup>3</sup> ) 1.0° 2.320 .3
Thickness   M <sub>r</sub>   J <sub>1</sub>   M <sub>r</sub>   J <sub>1</sub>   0°    V <sub>d</sub>   µ <sub>r</sub>	(m) Materials  0.050 Asphalt Concrete 0.484 C.S. (thawed) 0.198 G.S. (thawed) 0.794 G.S. (trace) 1.524 Subgrade 24 April 1979 (Day 114)  Plate Pressure (kPa):  Thickness (m) Materials	(NPa) (LPa)  9 391.0 46.9 - 67.68 4057.5 toct=13.40 34.9 - 45.53 37.6 - 57.81 165.7 - 62.86 200.0	9391.0 62.9 -128.2 2398.6 toct= 29.5 19.1 - 58.1 39.4 - 66.8 169.9 - 65.1	or Y <sub>d</sub> µ (kPa) (Ng/m <sup>3</sup> ) 1.0° 2.320 .3
0.050 Asphalt Concrete 433.0 12.3° 2.320 .45 0.180 G.5. (themed) 61.8 -102.8 10.5 kFa 1.517 .35 0.228 G.5. (themed) 45.6 48.15 10.0 kFa 1.517 .35 0.332 G.5. (themed) 40.4 - 42.24 10.0 kFa 1.516 .35 0.332 G.5. (themed) 40.4 - 58.86 15.0 kFa 1.516 .35 1.526 Subgrade 166.4 1.055 .35  Bubgrade 200.0 200.0 1.055 .35  12 February 1979 (Day 43)  Plate Pressure (kFa): 280.0 T(°C)  Thickness (m) Materials (NFa) (kFa) (	0.050 Asphalt Concrete 0.484 G.S. (thawed) 0.198 G.S. (frozen) 0.058 G.S. (thawed) 0.734 G.S. (rec.) 1.524 Subgrade 24 April 1979 (Day 114) Plate Pressure (kPa): Thickness (m) Materials	9391.0 46.9 - 67.68 4057.5 toct=13.40 34.9 - 45.53 37.6 - 57.81 165.7 - 62.86 200.0	9391.0	1.0° 2.320 .3
0.228 G.S. (thewed) 45.6 - 48.15 12.0 kPa 1.525 .35 0.332 G.S. (thewed) 40.4 - 42.24 10.0 kPa 1.516 .35 0.734 G.S. (rec.) 37.8 - 58.86 1.5 kPa 1.656 .35 1.524 Subgrade 166.4 1.055 .35 1.524 Subgrade 200.0 200.0 1.055 .35 1.524 Subgrade 200.0 200.0 1.055 .35 1.524 Subgrade 200.0 200.0 1.055 .35 1.524 Subgrade 200.0 Subgrade 200.0 1.055 .35 1.525 Subgrade 200.0 Subgrade 20	0.484 G.S. (thawed) 0.198 G.S. (frozen) 0.058 G.S. (thawed) 0.734 G.S. (rec.) 1.524 Subgrade - Subgrade 24 April 1979 (Day 114) Plate Pressure (kPa): Thickness (a) Materials	46.9 - 67.68 4057.5 toct=13.40 34.9 - 45.53 37.6 - 57.81 165.7 - 62.86 200.0	62.9 -128.7 2398.6 voct= 29.5 39.1 - 58.1 39.4 - 64.8 169.9 - 65.1	10 10
0.734 G.S. (rec.) 37.8 - 58.86 1.5 MPa 1.456 .35 1.524 Subgrade 166.4 1.055 .35 1.524 Subgrade 200.0 200.0 1.055 .35 1.5 1.524 Subgrade 200.0 200.0 1.055 .35 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.	0.734 G.S. (rec.) 1.524 Subgrade - Subgrade 24 April 1979 (Day 114) Plate Pressure (kPa): Thickness (a) Materials	37.6 - 57.81 165.7 - 62.86 200.0	39.4 - 64.8 169.9 - 65.1	98 -0.4° 1.497 .3
= Subgrade 200.0 200.0 1.055 .35  12 February 1979 (Dey 43)  Plate Pressure (kPa): 280.0 560.2 T(**C)  Thickness   Hr	- Subgrade  24 April 1979 (Day 114)  Plate Pressure (kPa):  Thickness (m) Materials	256.3		87 0.0 kPa 1.440 .3
Late Pressure (kPa): 280.0 560.2 T(*C)  hickness   Hr	Place Pressure (kPa): Thickness (m) Materials	256.3		18 1.055 .3 1.055 .3
hickness   H <sub>c</sub>   J <sub>1</sub>   H <sub>r</sub>   J <sub>1</sub>   V <sub>2</sub>   V <sub>3</sub>   V <sub>4</sub>   V <sub>7</sub>   V <sub>8</sub>   V <sub>8</sub>	Thickness (m) Materials			
Thickness Mr J <sub>1</sub> Mr J <sub>1</sub> Vr V <sub>d</sub> Vr V	(m) Materials		535.9	
(m) Materials (NFa) (kPa) (kPa) (kPa) (kPa) (kPa) (kPa) (NFa) (NFa	(m) Materials	H <sub>E</sub> J <sub>L</sub>		T(*C)
1.050 Asphalt Concrete 15019.0 15019.0 8.8° 2.320 .30 .1.00 G.8. (frazen) 45561.3 roct=52.73 27325.7 roct=111.00 -7.5° 1.516 .35 .1.240 G.8. (frazen) 31534.4 roct=29.73 8800.7 roct=54.79 -251° 1.524 .35 .1.40 -37.69 32.4 -40.61 10.0 kPa 1.516 .35 .35 .324 G.8. (rec.) 31.4 -37.69 32.4 -40.61 10.0 kPa 1.516 .35 .35 .324 G.8. (rec.) 38.0 -59.39 38.7 -62.11 3.9 kPa 1.475 .35	0.050 Apphalt Concents	H <sub>r</sub> J <sub>i</sub> (HPa) (NPa)	H <sub>r</sub> J <sub>l</sub> (MPa)	Ψ <sup>Y</sup> d μ (kPa) (kg/m <sup>3</sup> )
1.240 G.S. (fromen) 13353.4 toct=29.73 8800.7 toct= 54.79 -251* 1.524 .35	0.408 G.S. (thawed)	5531.0 51.1 - 62.42	5531.0 68.2 -116.	9.1° 2.320 .4 .80 11.8 kPa 1.524 .3
38.0 - 59.39 38.7 - 62.11 3.9 Mg 1.475 35	0.332 G.S. (thawed)- 0.734 G.S. (thawed)	40.1 - 42.29 37.9 - 58.92	44.9 - 53.	.66 9.6 kPa 1.515 .3 .38 2.5 kPa 1.463 .3
	1.524 Subgrade - Subgrade	166.5 - 63.35	170.5 - 15.	.52 1.055 .3
- Subgrade 200.0 200.0 1.055 .35	8 May 1979 (Day 128)	200.0	200.0	1.055 .3
Merch 1979 (Day 65)	Plate Pressure (kPs):	261.8	548.2	
late Pressure (kPa): 103.3 257.5	11800 11888000 (1287)			T(°C)
hickness M <sub>e</sub> J <sub>1</sub> M <sub>e</sub> J <sub>1</sub> V Y <sub>d 1</sub> V <sub>e</sub>	Thickness	M J	M <sub>T</sub> J <sub>1</sub>	Yan Ya
(m) Materials (MPa) (kPa) (kPa) (kPa) (kPa) (Mg/m <sup>3</sup> )	(m) Materials 0.050 Asphalt Concrete	(MPa) (kPa)	(MPa) (kPa) 3117.0	(kPa) (Hg/m²) 16.25° 2.320 .50
.0.00 Amphait Concrete 7443.0 7433.0 4.8* 2.320 .40 1.200 G.95*(thawed) 34.8 - 58.11 53.6 -148.1 0.0 kPa 1.446 .35	0.408 G.S. (thawed) 0.332 G.S. (thawed)	53.5 - 69.10 40.4 - 42.83		10 11.8 kPa 1.524 .50
0.480 G.S. (frozen) 34.8 toct= 5.10 3951.7 toct= 13.94 -0.4 kPs 1.446 .35 0.794 G.S. (frozen) 7851.6 50.64 36.1 - 52.65 1.9 kPs 1.460 .35	0.734 G.S. (rec.) 1.524 Subgrade	37.9 - 59.11 166.7 - 63.43	39.6 - 65.7 170.8 - 65.6	73 2.8 kPa 1.466 .35
1.524 Subgrade	- Subgrade	200.0	200.0	1.055 .35
13 March 1979 (Day 72)	30 May 1979 (Day 150)			
Plate Pressure (kPa): 259.0 583.0 T(*C)	Plate Pressure (kPa):	296.0	557.8	T(*C)
Thickness Me J <sub>1</sub> Me J <sub>1</sub> or T <sub>d 3</sub> ve	Thickness	H <sub>e</sub> J <sub>i</sub>	H <sub>e</sub> J	or "d "r
(m) Materials (MPa) (kPa) (kPa) (kPa) (kPa) (Mg/m <sup>3</sup> )	(m) Materials	(IPa) (ItPa)	(IPa) (kPa)	(LPa) (Hg/m²)
0.050 Apphalt Concrete 10382.2 10382.00.8" 2.320 .35 0.070 G.S. (frozen) 794.6 toct=146.33 559.9 toct=244.53 -0.4" 1.475 .35	0.050 Asphalt Concrete 0.408 G.S. (thewed)	2970.0 52.8 - 76.75	2970.0 68.1 -132.90	
0.330 G.S. (thawed) 33.7 - 41.38 44.6 - 76.22 4.2 MPa 1.478 .35 0.280 G.S. (thawed) 37.4 - 41.42 43.2 - 56.45 7.8 kPa 1.502 .40	0.332 G.S. (thawed) 0.734 G.S. (rec.)	39.4 - 44.76 38.0 - 59.60	43.7 - 56.90 39.6 - 65.71	L 0.0 kPa 1.444 .35
0.794 G.S. (rec.) 37.3 - 56.78 39.2 - 64.01 0.0 kPa 1.645 .35 1.524 Subgrade 165.2 - 62.64 169.6 - 65.03 1.055 .35	1.524 Subgrade = Subgrade	166.4 - 63.27 200.0	170.2 - 65.31 200.0	1 1.055 .35 1.055 .35
= Subgrade 200.0 200.0 1.055 .35	25 July 1979 (Day 206)			
21 March 1979 (Day 80)	Flate Pressure (kPa):	283.7	582.5	t(*c)
Plate Pressure (kPa): 268.6 503.0 T(*C)	Thickness	H <sub>E</sub> J <sub>1</sub>	H <sub>e</sub> J <sub>1</sub>	or * Ya. Pr
Thickness N <sub>r</sub> J <sub>1</sub> N <sub>r</sub> J V d N <sub>r</sub> (m) Macerials (MPs) (kPs) (MPs) (kPs) (kPs) (kPs) (kPs) (kPs) (Mg/m <sup>2</sup> )	(m) Materials	(HPa) (LPa)	(KPa) (KPa)	(kPa) (Na/m <sup>3</sup> )
0.050 Apphalt Concrete 7835.0 7835.0 4.0° 2.320 .40	0.050 Asphalt Concrete 0.408 G.S. (thawed)	1027.0 63.8 - 85.16	1027.0 85.2 -158.9	27.55° 2.320 .50 90 14.3 kPa 1.532 .35
0.240 G.S. (thawed) 54.1 -104.10 72.1 -194.9 5.9 kPa 1.488 .35 0.410 G.S. (frozen) 4429.1 roct=11.79 2790.7 roct= 23.29 -0.4° 1.490 .35	0.332 G.S. (thawed) 0.734 G.S. (rec.)	43.6 - 43.77 38.1 - 59.86	48.8 - 55.8	85 12.0 kPa 1,525 ,35 78 3.5 kPa 1,471 ,35
0.734 G.S. (rec.) 36.9 - 55.26 37.9 -59.91 1.9 kPa 1.459 .35 1.524 Subgrade 165.3 - 62.70 169.7 -65.03 1.055 .35	1.524 Subgrade - Subgrade	167.4 - 63.81 200.0	171.7 - 66.1 200.0	15 1,055 ,35 1,055 ,35
- Subgrade 200.0 200.0 1.055 .35	27 September 1979 (Day 2			
28 March 1979 (Day 87)	Plate Pressure (kPa):	286.4	594.8	
Plate Pressure (kPa): 267.2 548.2 T(*C)				T(*C) or
Thickness H J H J Or Thickness H J H H J H H H H H H H H H H H H H H	Thickness (m) Hateriels	H <sub>e</sub> J <sub>1</sub> (MPa) (kPa)	H <sub>c</sub> J <sub>1</sub> (MPa) (MPa)	Ψ Y <sub>d</sub> H <sub>E</sub> (kPm) (Ng/m <sup>3</sup> )
(a) Materiala (MPa) (MPa) (MPa) (MPa) (MPa) (Mp/a)	0.050 Asphalt Concrete	4366.0	4366.0	12.2* 2,320 .45
0.050 Asphalt Concrete 10466.0 10466.00.95* 2.320 .35	07108 G.S. (thawed) 0.228 G.S. (thawed) 0.332 G.S. (thawed)	64.5 -112.80 46.8 - 50.99	58.0 - 80.94	10.5 kPa 1.517 .35 12.0 kPa 1.525 .35
.091 G.S. (fromen) 942.4 roct=113.91 662.0 roct=191.18 -0.4 kPm 1.496 .35		40.9 - 43.43	39.8 - 66.54	
).091 G.S. (frosen) 942.4 toct=113.91 662.0 toct=191.18 -0.4 MPs 1.496 .35 ).265 G.S. (themed) 45.6 68.69 64.1 143.50 6.6 MPs 1.494 .35 ).384 G.S. (rec.) 6648.3 toct= 8.61 3886.5 toct= 20.44 -0.6* 1.489 .35	0.734 G.S. (rec.)	38.0 - 59.51	171.2 - 65.86	5 1.055 .35 1.055 .35
1.091 G.S. (frozen)	0.734 G.S. (rec.) 1.524 Subgrade = Subgrade	38.0 - 59.51 166.8 - 63.47 200.0	200.0	
1.091 G.S. (frosen)   942.6 toct=113.91   662.0 toct=191.18 -0.4 kPa 1.496 .35     1.265 G.S. (theward)   45.6   68.69   64.1   143.50   6.6 kFa 1.494 .35     1.384 G.S. (rec.)   6648.3 toct= 8.61   3886.5 toct= 20.44 -0.6*   1.489 .35     1.394 G.S. (rec.)   36.8   -54.92   38.0   -59.41   0.0 kPa 1.444 .35	0.734 G.B. (rec.) 1.524 Subgrade Subgrade	166.8 - 63.47 200.0	100.0	
0.091 G.S. (frozen)   942.4 voct= 13.91   662.0 voct= 91.18 -0.4 kPs 1.1496 .35   0.265 G.S. (thewed)   45.6   68.69   64.1   14.50   6.6 kPs 1.494 .35   0.386 G.S. (rec.)   6648.3 voct=  8.61   3686.5 voct=  20.44 -0.6*   1.489 .35   0.394 G.S. (rec.)   36.8 - 54.92   38.0 - 59.41   0.0 kPs 1.444 .35   0.526 Subgrade   164.9 - 62.48   168.8 - 64.54 1.055 .35   0.526 Subgrade   200.0 200.0 1.055 .35   0.527 Subgrade   200.0 200.0 1.055 .35   0.528 Subgrade   200.0 200.0 1.055 .35   0.538 Subgrade   200.0	0.734 G.S. (rec.) 1.524 Subgrade - Subgrade - Subgrade 19 Hovember 1979 (Day 32	166.8 ~ 63.47 200.0		
1091 G.S. (frozen)	0.734 G.B. (rec.) 1.524 Subgrade Subgrade	166.8 - 63.47 200.0 3)	590.7	T(*C)
1091 G.S. (frozen)	0.734 G.S. (rec.) 1.524 Subgrade  Bubgrade  19 Hovember 1979 (Day 22 Plate Pressure (kPa): Thickness	166.8 - 63.47 200.0 3) 	590.7 N <sub>e</sub> J <sub>1</sub>	οτ Ψ Y <sub>d</sub> γ <sub>c</sub>
1.091 G.S. (frozen)   942.4 toct= 13.91   662.0 toct= 91.18 -0.4 Mps 1.1496 .35     2.265 G.S. (thewed)   45.6   68.69   64.1   143.50   6.6 Mps 1.494 .35     2.386 G.S. (rec.)   6648.3 toct=  8.61   3686.5 toct=  20.44 -0.6*   1.489 .35     2.394 G.S. (rec.)   36.8   -36.92   38.0   -99.41   0.0 Mps 1.489 .35     2.326 Subgrade   164.9   -62.48   168.8   -64.54     1.055 .35     Subgrade   200.0     200.0       1.055 .35     Subgrade   200.0     300.0       1.055 .35     (1) Hoduli, stresses, and strains calculated by MELAPAV     (2)   M <sub>p</sub> = resilient modulus, J <sub>1</sub> = first stress invariant or bulk stress, φ = moisture tension, γ <sub>d</sub> = dry unit weight, μ <sub>p</sub> = resilient Poisson's ratio	0.734 G.S. (rec.) 1.524 Subgrade  Bubgrade  19 Hovember 1979 (Day 32 Plate Pressure (kPa):  Thickness (m) Materials	166.8 - 63.67 200.0 3) 376.8 Hr J (MPa) (MPa)	590.7	φτ γ <sub>d</sub> μ <sub>τ</sub> (kPa) (Hg/m <sup>3</sup> ) 6.35° 2.320 .40
1.091 G.S. (frozen)   942.4 roct= 13.91   662.0 roct= 91.18 -0.4 Mps 1.146 .35     1.265 G.S. (thewed)   45.6   66.89   64.1   143.50   6.6 Mps 1.494 .35     1.386 G.S. (rec.)   6648.3 roct= 8.61   3686.5 roct= 20.44 -0.6*   1.489 .35     1.394 G.S. (rec.)   36.8 - 36.92   38.0   -39.41   0.0 Mps 1.444 .35     1.324 Subgrade   164.9 - 62.48   168.8   -64.54     1.055 .35     3.38 Subgrade   200.0     200.0     1.055 .35     3.39 Subgrade   200.0     200.0     1.055 .35     4.30 Subgrade   200.0     200.0     1.055 .35     5.30 Subgrade   200.0     200.0     1.055 .35     6.30 Subgrade   200.0     200.0     1.055 .35     7.30 Subgrade   200.0     200.0     1.055 .35     8.30 Subgrade   200.0     200.0     1.055 .35     9.30 Subgrade   200.0     200.0     200.0     200.0     200.0     9.30 Subgrade   200.0     200.0     200.0     200.0     200.0     200.0     9.30 Subgrade   200.0     200.0	0.734 G.S. (rec.) 1.524 Subgrade  Bubgrade  19 Hovember 1979 (Day 22 Plate Pressure (kPa): Thickness	166.8 - 63.67 200.0 3) 376.8 Hr J (MPa) (MPa)	590.7 N <sub>r</sub> J <sub>1</sub> (NPa) (kPa)	οτ Ψ Υ <sub>d</sub> μ <sub>r</sub> (kPa) (Ng/m <sup>3</sup> ) 6.35* 2.320 .40 12.0 kPa 1.525 .35 10.0 kPa 1.516 .35
1.091 G.S. (frozen)   942.4 roct= 13.91   662.0 roct= 91.18 -0.4 kps 1.366 .35     2.655 G.S. (thewed)   45.6   68.69   64.1   143.50   6.6 kps 1.494 .35     2.656 G.S. (trec.)   6648.3 roct= 8.61   3686.5 roct= 20.44 -0.6*   1.489 .35     2.944 G.S. (rec.)   36.8   -36.92   38.0   -39.41   0.0 kps 1.444 .35     2.924 G.S. (rec.)   36.8   -36.92   38.0   -39.41   0.0 kps 1.444 .35     3.524 Subgrade   164.9   -92.48   168.8   -94.54     1.055   35     3.526 Subgrade   200.0     200.0     1.055   35     3.527 Subgrade   200.0     200.0     1.055   35     4.528 Subgrade   200.0     200.0     1.055   35     5.528 Subgrade   200.0     200.0     1.055   35     6.529 Subgrade   200.0     200.0     1.055   35     7.529 Subgrade   200.0     200.0     1.055   35     8.529 Subgrade   200.0     200.0     1.055   35     9.529 Subgrade   200.0     200.0     1.055   35     9.529 Subgrade   200.0     200.0     1.055   35     9.529 Subgrade   200.0	0.734 G.S. (rec.) 1.524 Subgrade  — Subgrade  19 November 1979 (Day 32 Plate Pressure (kPa):  Thickness (a) Materials  0.050 Asphalt Concrete 0.108 G.S. (thawed)	166.8 - 63.47 200.0 3) 376.8 M <sub>F</sub> J <sub>1</sub> (MPa) (APa) 6715.0 62.3 -94.43	590.7  N <sub>r</sub> J <sub>1</sub> (NPa) (kPa)  6715.0  87.2 -195.30	0τ Y <sub>d</sub> μ <sub>τ</sub> (kPa) (Ng/m <sup>3</sup> ) 6.35° 2.320 .40 12.0 kPa 1.525 .35 10.0 kPa 1.516 .35 6.0 kPa 1.504 .35
1.091 G.S. (frozen)	0.734 G.S. (rec.) 1.524 Subgrade  1.526 Subgrade  19 November 1979 (Day 32 Plate Pressure (kPa):  Thickness (a) Materials 0.050 Asphalt Concrete 0.108 G.S. (thawed) 0.228 G.S. (thawed) 0.232 G.S. (thawed) 0.734 G.S. (tec.) 1.524 Subgrade	166.8 - 63.47 200.0 3)	590.7  N <sub>r</sub> (NPa)  6715.0  87.2  -199.50  31.3  -77.09  43.2  -55.85  39.8  -66.25  17072  -65.37	0 T T d 3 PT (Ng/m) - 10 Ng/m - 10 N
1.051 G.\$. (frosen)   942.4 toct= 13.9  662.0 toct= 91.18 -0.4 MFB 1.496 .35   0.265 G.\$. (thewed)   45.6   68.69   64.1   14.350   6.6 MFB 1.494 .35   0.265 G.\$. (rec.)   6648.3 toct=  8.61   3646.5 toct=  20.44   -0.6*   1.489   .35   0.364 G.\$. (rec.)   36.8   -36.92   38.0   -39.41   0.0 MFB 1.444   .35   0.374 G.\$. (rec.)   36.8   -36.92   38.0   -39.41   0.0 MFB 1.444   .35   0.374 G.\$. (rec.)   36.8   -36.92   38.0   -39.41   0.0 MFB 1.444   .35   0.375 Maybgrade   164.9   -62.48   168.8   -64.34     1.055   .35   0.385 Maybgrade   200.0     200.0       1.055   .35   0.395 Maybgrade   200.0     200.0       1.055   .35   0.397 Maybgrade   200.0     200.0       1.055   .35   0.398 Maybgrade   200.0     200.0       1.055   .35   0.398 Maybgrade   200.0     200.0       1.055   .35   0.399 Maybgrade   200.0     200.0     1.055   .35   0.399 Maybgrade	0.734 G.S. (rec.) 1.524 Subgrade  Bubgrade  19 Hovember 1979 (Day 32  Plate Pressure (kPs):  Thickness (m) Hateriels 0.050 Asphalt Concrete 0.108 G.S. (chawed) 0.325 G.S. (thawed) 0.325 G.S. (thawed) 0.325 G.S. (thawed) 0.332 G.S. (rec.)	166.8 - 63.47 200.0 3)	H <sub>T</sub> J <sub>1</sub> (NPa) (kPa)  6715.0 87.2 -195.30 53.3 -77.09 43.2 -55.85 39.8 - 66.23	0T Yd 3 Fr (kPa) (Ng/m)
0.091 G.S. (frosen) 902.4 roct= 13.9  662.0 roct= 91.18 -0.4 Mrs 1.496 .35 0.255 G.S. (thewed) 45.6 68.69 64.1 143.50 6.6 Mrs 1.496 .35 0.256 G.S. (thewed) 45.6 68.69 64.1 143.50 6.6 Mrs 1.498 .35 0.364 G.S. (rec.) 6648.3 roct= 8.61 3646.5 roct= 20.44 -0.6* 1.489 .35 0.794 G.S. (rec.) 36.8 -54.92 38.0 - 59.41 0.0 Mrs 1.484 .35 1.574 Subgrade 164.9 -62.48 168.8 -64.54 -1.055 .35 m. Subgrade 200.0 200.0 1.055 .35 m. Subgrade 200.0 200.0 1.055 .35 0.0 m. Subgrade 200.0 200.0 200.0 1.055 .35 0.0 m. Subgrade 200.0 200.0 200.0 1.055 .35 0.0 m. Subgrade 200.0 200.	0.734 G.S. (rec.) 1.524 Subgrade  1.526 Subgrade  19 November 1979 (Day 32 Plate Pressure (kPa):  Thickness (a) Materials 0.050 Asphalt Concrete 0.108 G.S. (thawed) 0.228 G.S. (thawed) 0.232 G.S. (thawed) 0.734 G.S. (tec.) 1.524 Subgrade	166.8 - 63.47 200.0 3)	590.7  N <sub>r</sub> (NPa)  6715.0  87.2  -199.50  31.3  -77.09  43.2  -55.85  39.8  -66.25  17072  -65.37	0 T T d 3 PT (Ng/m) - 10 Ng/m - 10 N
0.091 G.S. (frosen) 942.4 τoct= 13.9  662.0 τoct= 91.18 -0.4 Mrs 1.496 .35 0.255 G.S. (thewed) 45.6 68.69 64.1 14.350 6.6 Mrs 1.496 .35 0.265 G.S. (thewed) 45.6 68.69 64.1 14.350 6.6 Mrs 1.491 .35 0.266 G.S. (rec.) 6648.3 τoct= 8.61 3646.5 τoct= 20.44 -0.6* 1.489 .35 0.294 G.S. (rec.) 36.8 - 54.92 38.0 - 59.41 0.0 Mrs 1.444 .35 1.524 Subgrade 164.9 - 62.48 168.8 - 64.54 - 1.055 .35 m. Subgrade 200.0 200.0 1.055 .35 0.200.0 1.055 .35 0.200.0	0.734 G.S. (rec.) 1.524 Subgrade  1.526 Subgrade  19 November 1979 (Day 32 Plate Pressure (kPa):  Thickness (a) Materials 0.050 Asphalt Concrete 0.108 G.S. (thawed) 0.228 G.S. (thawed) 0.232 G.S. (thawed) 0.734 G.S. (tec.) 1.524 Subgrade	166.8 - 63.47 200.0 3)	590.7  N <sub>r</sub> (NPa)  6715.0  87.2  -199.50  31.3  -77.09  43.2  -55.85  39.8  -66.25  17072  -65.37	0 T T d 3 PT (Ng/m) - 10 Ng/m - 10 N
0.091 C.S. (frosen) 942.4 toct= 13.9  662.0 toct= 91.18 -0.4 MPs 1.496 .35 0.255 C.S. (thewed) 45.6 68.69 64.1   14.350 6.6 MPs 1.494 .35 0.265 C.S. (thewed) 45.6 68.69 64.1   14.350 6.6 MPs 1.494 .35 0.364 C.S. (trec.) 6648.3 toct= 8.01 3646.5 toct= 20.44 -0.6* 1.489 .35 0.394 C.S. (rec.) 36.8 - 56.92 38.0 - 59.41 0.0 MPs 1.444 .33 1.524 Subgrade 164.9 - 62.48 168.8 - 66.54 1.055 .35 m Subgrade 200.0 200.0 200.0 1.055 .35 m Subgrade 200.0 20	0.734 G.B. (rec.) 1.524 Subgrade  19 Hovember 1979 (Day 32 Plate Pressure (kPs):  Thickness (m) Materials 0.050 Asphalt Concrete 0.108 G.B. (thewed) 0.228 G.B. (thewed) 0.312 G.B. (thewed) 0.312 G.B. (thewed) 0.312 G.B. (thewed) 0.314 G.B. (thewed) 0.315 G.B. (thewed) 0.315 G.B. (thewed) 0.315 G.B. (thewed) 0.316 G.B. (thewed) 0.317 G.B. (thewed) 0.317 G.B. (thewed) 0.318 G.B. (thewed) 0.318 G.B. (thewed) 0.319 G.B. (thewed) 0.319 G.B. (thewed)	376.8  Hr J (NPa) (NPa)  6715.0 62.3 -94.63 42.8 -47.86 38.3 -42.99 37.9 -59.02 166.1 -63.14	590.7  N <sub>T</sub> J <sub>1</sub> (HPa) (kPa)  6715.0 87.2 -195.30 53.3 - 77.09 43.2 - 55.85 39.8 - 66.23 17072 - 65.57	0
<ul> <li>3.091 G.S. (frosen) 942.4 toct= 13.91 662.0 toct= 91.18 -0.4 Mps 1.1496 .35 0.265 G.S. (thewed) 45.6 68.69 64.1   14.50 6.6 Mps 1.494 .35 0.265 G.S. (rec.) 6648.3 toct= 8.61 3646.5 toct= 20.44 -0.6* 1.499 .35 0.346 G.S. (rec.) 36.8 - 56.92 38.0 - 99.41 0.0 Mps 1.494 .35   1.524 Subgrade 164.9 - 62.48 168.8 - 64.54 1.055 .35   1.524 Subgrade 200.0 200.0 200.0 1.055 .35   1.524 Subgrade 200.0 200.0 200.0 1.055 .35   1.524 Subgrade 200.0 200</li></ul>	0.734 G.B. (rec.) 1.524 Subgrade  19 Hovember 1979 (Day 32 Plate Pressure (kPs):  Thickness (m) Materials 0.050 Asphalt Concrete 0.108 G.B. (thewed) 0.228 G.B. (thewed) 0.312 G.B. (thewed) 0.312 G.B. (thewed) 0.312 G.B. (thewed) 0.314 G.B. (thewed) 0.315 G.B. (thewed) 0.315 G.B. (thewed) 0.315 G.B. (thewed) 0.316 G.B. (thewed) 0.317 G.B. (thewed) 0.317 G.B. (thewed) 0.318 G.B. (thewed) 0.318 G.B. (thewed) 0.319 G.B. (thewed) 0.319 G.B. (thewed)	376.8  Hr J (NPa) (NPa)  6715.0 62.3 -94.63 42.8 -47.86 38.3 -42.99 37.9 -59.02 166.1 -63.14	590.7  N <sub>T</sub> J <sub>1</sub> (HPa) (kPa)  6715.0 87.2 -195.30 53.3 - 77.09 43.2 - 55.85 39.8 - 66.23 17072 - 65.57	0
1.091 G.S. (frozen)   942.4 Toct= 13.91   662.0 Toct= 91.18 -0.4 Mps 1.146 .35     1.265 G.S. (thewed)   45.6   68.69   64.1   143.50   6.6 Mps 1.494 .35     1.386 G.S. (rec.)   6668.3 Toct= 8.61   3686.5 Toct= 20.44 -0.6*   1.489 .35     1.386 G.S. (rec.)   36.8   -36.92   38.0   -99.41   0.0 Mps 1.489 .35     1.326 Subgrade   164.9   -62.48   168.8   -64.34     1.055 .35     3.38 Subgrade   200.0     200.0     1.055 .35     3.39 Subgrade   200.0     200.0     1.055 .35     4.30 Subgrade   200.0     200.0     1.055 .35     5.30 Subgrade   200.0     200.0     1.055 .35     6.30 Subgrade   200.0     200.0     1.055 .35     7.30 Subgrade   200.0     200.0     1.055 .35     7.30 Subgrade   200.0     200.0     1.055 .35     8.30 Subgrade   200.0     200.0     1.055 .35     9.30 Subgrade   200.0     200.0     200.0     1.055 .35     9.30 Subgrade   200.0     200.0     200.0     200.0     9.30 Subgrade   200.0	0.734 G.S. (rec.) 1.526 Subgrade  19 November 1979 (Day 22 Plate Pressure (kPa):  Thickness (a) Haterials 0.050 Asphalt Concrete 0.106 G.S. (thawed) 0.228 G.S. (thawed) 0.228 G.S. (thawed) 0.332 G.S. (rec.) 1.524 Subgrade  5 Subgrade  6 Apr 24 Apr 8 May 344x10 <sup>-6</sup> 3.019x10 <sup>-6</sup> 3.937x	33)  376.8  N <sub>T</sub> J <sub>1</sub> (MPa)  6715.0  62.3  62.3  62.3  62.3  62.9  37.9  30.16	N <sub>T</sub>   J <sub>1</sub>   (NPa)   (NPa)	0
1091 G.S. (frozen)   942.4 roct= 13.91   662.0 roct= 91.18 -0.4 Mps 1.1496 .35   2455 G.S. (thewed)   45.6   68.69   64.1   13.50   64.6 Mps 1.494 .35   384 G.S. (rec.)   6648.3 roct= 8.61   3486.5 roct= 20.44 -0.6*   1.489 .35   394 G.S. (rec.)   36.8   -36.92   38.0   -39.41   0.0 Mps 1.444 .35   3524 Subgrade   164.9   -92.48   168.8   -64.54     1.055   35   3526 Subgrade   200.0     200.0       1.055   35   3536	0.734 G.B. (rec.) 1.526 Subgrade  19 November 1979 (Day 22 Plate Pressure (kPa):  Thickness (a) Naterials 0.050 Asphalt Concrate 0.106 G.E. (thawed) 0.226 G.E. (thawed) 0.232 G.E. (thawed) 0.232 G.E. (thawed) 0.234 G.E. (thawed) 0.235 G.E. (thawed) 0.236 G.E. (thawed) 0.236 G.E. (thawed) 0.736 G.E. (thawed) 0.737 G.E. (thawed) 0.738 G.E. (thawed)	376.8  N <sub>g</sub> J <sub>1</sub> (MPa) (APa)  6715.0 62.3 -96.43 42.8 -67.86 38.3 -42.92 10-6 -3.14 200.0 -3.14 200.0 -5.56 10-6 -5.56 10-6 -5.56 10-6 -7.535×10-6 9.2	N <sub>T</sub>   J <sub>1</sub>   (NPa)   (NPa)	0

Table D2b. Resilient moduli and supporting data calculated by NELAPAV for Graves sand test section, 1980.

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25 February 1980 (Day 5	6)			29 March 1980 (Day 89)			
Place Pressure (kPs):	261.0	566.0	τ(*c)	Plate Pressure (kPs):	159.0	240.0	T(*C)
Thickness (a) Materiels	H <sub>r</sub> J <sub>1</sub> (hPa)	H <sub>e</sub> J <sub>I</sub> (jg/a) ( <u>k/a)</u>	or Y Y <sub>d</sub> µ <sub>r</sub> ( <u>kPa</u> ) (Ng/m <sup>3</sup> )	Thickness (m) Materials	H <sub>r</sub> J <sub>j</sub> (MPa) (kPa)	H J c (HPa) (kPa)	or Yd Fr (kPa) (Hg/a <sup>3</sup> )
0.050 Asphalt Concrete 0.150 G.S. (fresen) 0.300 G.S. (rec.) 0.300 G.S. (rec.) 0.524 G.S. (rec.) 1.524 Subgrade  Subgrade	12679.0 1489.0 roct=43.59 28.7 - 49.96 33.0 - 42.57 38.1 - 59.78 165.3 - 62.69 200.0	12679.0 917.4 roct** 88.66 31.4 - 37.82 34.7 - 47.97 39.3 - 64.30 169.3 - 64.84 200.0	-0.25° 2.320 35 -0.25° 1.497 35 11.5 kPa 1.522 35 2.0 kPa 1.460 35 2.0 kPa 1.460 35 1.055 35	0.050 Asphalt Concrete 0.350 G.S. (thewed) 0.250 G.S. (rec.) 0.250 G.S. (rec.) 0.524 G.S. (rec.) 1.524 Subgrade — Subgrade	6029.0 37.1 - 42.97 30.7 - 35.68 32.9 - 42.06 37.6 - 58.07 163.8 - 61.85 200.0	6029.0 43.97 -59.35 32.5 -40.78 33.9 -45.15 38.2 -60.04 165.0 -62.50 200.0	7.0 kPs 1.497 .35 3.5 kPs 1.470 .35 0.0 kPs 1.444 .35
12 March 1980 (Day 72)				3 April 1980 (Day 94)			
Plate Pressure (kPa):	250.0	550.0	T(*C)	Plate Pressure (kPa):	200.0	255.0	τ(*c)
Thickness (m) Materials	H Ji (HPa) (kPa)	H <sub>T</sub> J <sub>1</sub> (KPa)	οτ Ψ Υ <sub>d</sub> μ <sub>r</sub> (kPa) (Ng/a <sup>3</sup> )	Thickness (m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa)	H <sub>r</sub> J <sub>l</sub> (MPa)	or * Y <sub>d</sub> y <sub>r</sub> (kPa) (Ng/m <sup>3</sup> )
0.050 Asphalt Concrete 0.100 G.S. (thewed) 0.250 G.S. (frozen) 0.600 G.S. (rec.) 0.524 G.S. (rec.) 1.524 Subgrade  Subgrade	7377.0 66.5 -233.50 1723.3 toct=30.35 31.5 - 37.95 38.2 - 60.11 164.5 - 62.25 200.0	7377.0 96.7 - 52.80 962.4 toct= 71.30 34.3 - 46.47 39.6 - 65.59 168.6 - 64.47 200.0	7.0° 2.320 .40 0.0 kPa 1.444 .35 -0.1° 1.449 .35 6.0 kPa 1.490 .35 0.0 kPa 1.444 .35 1.055 .35 1.055 .35	0.050 Asphalt Concrete 0.350 G.S. (thawed) 0.362 G.S. (rec.) 0.381 G.S. (rec.) 0.381 G.S. (rec.) 1.524 Subgrade  Subgrade	4150.0 43.0 - 55.36 32.1 - 39.57 35.3 - 49.76 39.4 - 64.78 165.0 - 62.52 200.0	4150.0 47.2 -67.39 33.1 -42.56 35.7 -51.36 39.7 -66.11 165.8 -62.95 200.0	7.5 kPa 1.501 .35 0.5 kPa 1.449 .35 0.0 kPa 1.444 .35
19 March 1980 (Day 79)				10 April 1980 (Day 101			
Plate Pressure (kPa):	267.0		T(*C)	Plate Pressure (kPa):	235.0	334.0	T(*C)
Thickness (m) Hateriels	H <sub>T</sub> J <sub>1</sub> (HPa)	N <sub>r</sub> J <sub>i</sub> (HPa) (kPa)	or † '\(\frac{1}{4}\) \(\frac{1}{4}\) \(\frac{1}{1}\) \(\frac{1}\) \(\fra	Thickness (m) Materials	H <sub>E</sub> J <sub>1</sub> (kPa)	H <sub>r</sub> J <sub>l</sub> (MPa)	οτ Ψ γ <sub>d</sub> μ <sub>τ</sub> (kPa) (Ng/a <sup>3</sup> )
0.050 Asphalt Concrete 0.124 G.S. (thawed) 0.326 G.S. (frozen) 0.362 G.S. (rec.) 0.762 G.S. (rec.) 1.524 Subgrade  Subgrade	5918.0 90.6 -458.60 1389.4 toct=44.93 29.6 -32.66 36.7 - 54.54 164.4 - 62.21 200.0	   	9.95* 2.320 .45 0.0 kPa 1.444 .35 -0.15* 1.460 .35 7.0 kPa 1.497 .35 0.0 kPa 1.494 .35 1.055 .35 1.055 .35	0.050 Asphalt Concrete 0.350 G.S. (thawad) 0.362 G.S. (rec.) 0.381 G.S. (rec.) 0.381 G.S. (rec.) 1.524 Subgrade  — Subgrade	5021.0 41.7 - 60.74 32.5 - 40.87 35.3 - 49.99 39.4 - 64.79 164.4 - 62.21 200.0	5021.0 47.8 -81.76 34.2 -42.16 36.2 -52.84 40.0 -67.17 165.9 200.0	4.0 MPm 1.475 .35 0.0 MPm 1.444 .35
22 March 1980 (Day 82)				17 April 1980 (Day 108)			
Plate Pressure (kPa):	185.0		T(*C)	Plate Pressure (kPa):	230.0	322.0	T(*C)
Thickness (m) Materials	H <sub>E</sub> J <sub>1</sub> (HPa) (kPa)	H <sub>r</sub> J <sub>i</sub> (HPa) (hPa)	οτ Ψ Υ <sub>d</sub> ν <sub>τ</sub> (kPa) (Hg/m)	Thickness (m) Materials	M <sub>r</sub> J <sub>1</sub> (MPa) (kPa)	H <sub>r</sub> J <sub>1</sub> (MPa) (kPa)	or Ψ Y <sub>d</sub> μ <sub>r</sub> (kPa) (Mg/a <sup>3</sup> )
0.050 Asphalt Concrete 0.150 G.S. (thewed) 0.300 G.S. (rec.) 0.300 G.S. (rec.) 0.324 G.S. (rec.) 1.524 Subgrade  — Subgrade	8958.0 31.0 - 44.85 31.2 - 37.10 33.7 - 44.75 38.2 - 60.12 165.2 - 61.55 200.0		4.4° 2.320 .40 0.0 kPa 1.444 .35 5.0 kPa 1.482 .35 0.0 kPa 1.444 .35 0.0 kPa 1.444 .35 1.055 .35 1.055 .35	0.050 Asphalt Concrete 0.350 G.S. (thewed) 0.362 G.S. (rec.) 0.381 G.S. (rec.) 0.381 G.S. (rec.) 1.526 Subgrade 6 Subgrade	4260.0 47.8 - 61.02 32.4 - 40.73 35.4 - 50.30 39.5 - 65.18 165.1 - 62.57 200.0	4260.0 54.4 -80.73 34.0 -45.50 36.2 -52.89 40.0 -67.34 166.4 -63.29 200.0	8.0 kPs 1.504 .35 0.0 kPs 1.444 .35 0.0 kPs 1.444 .35
26 March 1980 (Day 86)							
Plate Pressure (kPa):	238.0		T(*C)	* Notes: (1) Moduli, stre	sees, and strains	calculated by MELA	PAV
Thickness (m) Materials	H <sub>r</sub> J <sub>1</sub> (MPa)	H <sub>r</sub> J <sub>1</sub> (MPa) (MPa)	or Y <sub>d</sub> µ <sub>r</sub> (upa) (Mg/m)				ant or bulk stress, resilient Poisson's
0.050 Asphalt Concrete 0.350 G.S. (thewed) 0.250 G.S. (rec.) 0.874 G.S. (rec.) 1.524 Subgrade	42.9 - 58.80 32.6 - 41.05 36.7 - 54.68 164.6 - 62.29		9.3° 2.320 .45 7.0 kPa i.497 .35 5.0 kPa i.482 .35 0.0 kPa i.444 .35 1.055 .35			O and center of re	spective layer
- Subgrade	200.0		1.055 .35	(5) Toct = octah	edral shear stress	(MPa)	

#### Tangential Strain $\epsilon_{c}$ (r = 0, s = .05) and Vertical Strain $\epsilon_{w}$ (r = 0, s = 1.524)

Table D3a	Resilient moduli an	d supporting date	celculated by	NELAPAV fo	r Hart Brothers	test section.	1979.
IAUK DJA.	Vesinent madrii en	u suppviume usu	i Carculateu DY	THE LAKE A VIII	I IIAII DIVINCIS	test sections	4717.

SSM ZZZZZZZ PRZEZZZ SSZZZZZ DODO

Note   1968   1969	O October 1978 (Day -63)	243.6	517.3 r(*c)	24 April 1979 (Day 114)  Plate Pressure (kPa): 264.2	551.6 T(°C)
Ministry		Hr J2/Toct	or Hr J <sub>2</sub> /Toct # Yd		or t <sup>M</sup> r <sup>J<sub>2</sub>/T</sup> oct <sup>6</sup> <sup>1</sup> d <sup>6</sup> r
Part	U.USU Asphalt Concrete 0.250 H.B.S. (thawed) 0.300 H.B.S. (thawed) 0.350 H.B.S. (thawed) 0.400 H.B.S. (thawed) 0.174 H.B.S. (thawed) 1.524 Subgrade	2034.0 44.8 44.11 49.5 55.03 77.7 159.95 125.8 466.16 174.7 1003.42 178.9 J <sub>3</sub> =-73.10	2034.0 20.9° 2.320 .50 48.9 53.44 10.0 kPa 1.840 .35 45.2 45.00 10.0 kPa 1.840 .33 65.7 110.48 9.0 kPa 1.840 .33 99.4 288.98 8.0 kPa 1.840 .33 137.4 590.33 8.0 kPa 1.840 .33 142.6 J75.24 1.055 .55	U.USO Asphalt Concrete 23/4.U	2524.0 19.5° 2.520 .50 3 48.2 50.75 10.3 kPa 1.840 .33 42.1 39.04 9.8 kPa 1.840 .33 2 53.1 109.85 4.9 kPa 1.820 .33 2 81.6 284.02 4.9 kPa 1.820 .33 114.4 598.59 4.9 kPa 1.820 .33 2 162.6 J <sub>j</sub> =-75.20 1.055 .35
This content		273.7	T(*C)		f(*C)
Column   C		Hr J/toct (MPa) (kPa)	$H_r = J_2/\tau_{oct} + \gamma_d = \mu_r$		t Mr J <sub>2</sub> /roct r d <sub>3</sub> r
Part	U.250 H.B.S. (frozen) 0.300 H.B.S. (frozen) U.350 H.B.S. (frozen) 0.400 H.B.S. (thawed) 0.174 H.B.S. 1.524 Subgrade	48/2.5 3686.7 1561.4 192.5 1118.16 242.5 2068.86 1/2.7 J =-67.83	8872.58.5* 1.584 .30 3686.74.9* 1.584 .30 1561.41.0* 1.584 .30 156.9 711.08 9.8 kPa 1.840 .33 197.7 1318.00 9.8 kPa 1.840 .33 197.5 368.87 1.055 .35	0.250 R.B.S. (thawed) 38.6 J2.25 0.300 R.B.S. (thawed) 44.1 43.10 0.350 B.B.S. (thawed) 59.6 147.11 0.400 H.B.S. (thawed) 98.9 449.8 0.174 H.B.S. (140.23 772.80 1.124 Subgrade 181.1 J <sub>1</sub> -2.27	7 w(1,3 35,3) 9.8 kPa 1.84(1 33) 5 38,7 32,39 9.0 kPa 1.84(1 33) 5 38,7 32,39 9.0 kPa 1.84(1 33) 5 38,6 74,4 74,4 kPa 1.82(1 33) 5 110,8 5 19,34 4,4 kPa 1.82(1 33) 6 110,8 5 19,34 4,4 kPa 1.82(1 33) 6 144,2 3,4 135(3 3) 144,2 3,4 135(3 3) 144,2 3,4 135(3 3)
Second   S		255.9			
Company   Content   Cont			or Mr J <sub>2</sub> /τ <sub>oct</sub> Ψ γ <sub>d 3</sub> μ <sub>r</sub>		t Mr J <sub>2</sub> /T <sub>oct</sub> or Y <sub>d 3</sub> µr
Note   Part	U.USU Aaphalt Concrete 0.270 H.B.S. (thawed) U.300 H.B.S. (frozen) 0.350 H.B.S. (frozen) U.400 H.B.S. (thawed) U.174 H.B.S. (thawed) U.174 H.B.S. (bubgrade  Subgrade	68/6.0 31.3 67.78 40.8 449.7 134.0 465./4 180.6 900.32 176.1 J <sub>.</sub> =69.65	68/6.0 6.1" 2.320 .40 37.7 102.42 0.0 kpa 1.780 .33 40.8 0.0" 1.584 .30 449.71.1" 1.584 .30 107.9 288.99 10.8 kpa 1.840 .33 183.0 537.74 10.8 kpa 1.840 .33 179.4 0.79.2 0.70 .105 .55	0.050 Asphalt Concrete 518.0 38.00 0.250 H.B.S. (theward) 35.6 38.00 0.300 H.B.S. (theward) 41.8 45.77 0.350 H.B.S. (theward) 58.7 147.44 0.400 H.B.S. (theward) 79.3 449.55 0.174 H.B.S. (theward) 136.2 975.00 1.524 Subgrade 179.5 J <sub>1</sub> -72.85	4 518.0 — 33.5° 2.320 .00 4 37.9 43.62 7.4 bbs 1.820 .33 6 49.9 102.81 3.9 bbs 1.820 .33 7 77.0 268.23 3.9 bbs 1.820 .33 7 108.7 573.97 3.9 bbs 1.820 .33 7 183.1 J <sub>1</sub> =7.53 — 1.035 .33
Secretary   Column	late Pressure (kPa):		Γ(*c)		T(*C)
2.20		(MPa) (kPa)	(MPa) (kPa) (kPa) (Ng/m²)	(m) Materials (MPa) (kPa)	(NPs) (kPs) (kPs) (Ng/m³)
Part   Presume (UPs)   Part   Part   Presume (UPs)   Part   Pa	0.250	40.3 118.56 449.7 654.1 40.8 128.1 1520.89 171.9 J;=67.45	52.8 215.15 U.U XP3 1,780 .50 449.71.* 1,584 .50 554.11.* 1,584 .50 40.8 U.1.* 1,584 .30 100.3 886.11 0.0 KP4 1,780 .33 172.9 1,~58.55 1,055 .55	0.250 H.B.S. (Chewed) 48.0 34.5 0.300 H.B.S. (Chewed) 49.6 43.2 0.350 H.B.S. (Chewed) 69.7 166.5 0.400 H.B.S. (Chewed) 104.5 437.7 0.174 H.B.B. 146.9 928.0 1.324 Subgrade 182.5 J73.8	8 49.0 36.17 13.0 Mga 1.860 .33 11 43.4 32.30 11.0 Mga 1.860 .33 16 54.7 104.08 6.5 Mga 1.820 .33 8 84.1 270.88 6.5 Mga 1.820 .33 77 117.6 1579.96 6.5 Mga 1.820 .33 2 183.7 J75.22 1.055 .35
Notice 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		258.7			T(*C)
0.000 Asphalf Concrete (1991)  0.000 Asphalf Concrete (1992)  0.000 Asphalf Concrete (1993)  0.000 Asphalf Concrete (1994)			Mr 32/Toct # Ya Fr	Thickness $\frac{H}{r}$ $J_2/\tau_{oc}$ $\underline{\hspace{1cm}}$ (MPa) (kPa)	. H_ J <sub>2</sub> /τ ψ γ <sub>4</sub> μ_
Tele   Plate	0.250 H.B.S. (thawed) 0.300 H.B.S. (thawed) 0.350 H.B.S. (frozen) 0.400 H.B.S. (thawed) 0.174 H.B.S. (thawed) 1.524 Subgrade	41.6 42.41 37.8 53.28 40.8 84.1 472.60 119.7 1029.92 177.9 J <sub>1</sub> =-70.96	45.1 50.64 8.3 kPa 1.840 .33 35.0 44.77 3.4 kPa 1.820 .33 40.8 0.0" 1.584 .30 66.9 284.83 1.0 kPa 1.800 .33 94.9 615.84 1.0 kPa 1.800 .33 179.5 J_=73.27 1.055 .35	0.250 H.B.S. (themmed) 45.3 45.1 0.300 H.B.S. (themmed) 43.6 55.2 0.350 H.B.S. (themmed) 62.4 156.1 0.400 H.B.S. (themmed) 101.3 454.8 0.174 H.B.S. 142.3 961.9 1.324 Subgrade 181.7 J <sub>1</sub> —72.8	8 48.9 53.40 10.0 kPa 1.800 .33 7 39.8 45.24 8.4 kPa 1.820 .33 5 53.2 109.87 5.0 kPa 1.820 .33 5 80.9 276.85 5.0 kPa 1.820 .33 9 113.1 579.40 5.0 kPa 1.820 .33 9 186.0 J <sub>2</sub> ~75.31 1.055 .35
htchness		264.2	1(*6)	<u></u>	T(*C)
0.250 RB.S.S. (Chawed) 84.5 99.11 47.0 126.34 7.8 kp 1.480 1.0 126.34 7.8 kp 1.0 126.34 7.8 kp 1.480 1		М <sub>г</sub> <sup>ј</sup> 2 <sup>/ т</sup> ост (MPa) (kPa)	Mr J./Tort # Yd wr		) (MPa) (kPa) (kPa) (Hg/a²)
Title Pressure (kPa):    253.2   566.6   T(°C)   T(°C)	0.250 H.B.S. (thawed) 0.300 H.B.S. (thawed) 0.350 H.B.S. (thawed) 0.400 H.B.S. (frozen) 0.174 H.B.S. 1.524 Subgrade	41.5 96.11 42.3 66.77 58.3 209.97 1073.5 — 133.2 1302.02 178.0 J <sub>1</sub> —70.71	47.0 126.34 7.4 kPa 1.820 .33 40.5 60.56 4.9 kPa 1.820 .33 53.0 170.16 1.0 kPa 1.800 .30 1073.55* 1.584 .30 106.7 799.30 1.0 kPa 1.800 .33 179.4 3,=-73.14 1.055 .35	0,250 H.B.S. (thawed) 48.5 52.4 0,300 H.B.S. (thawed) 49.6 55.7 0,350 H.B.S. (thawed) 86.4 161.4 0,400 H.B.S. (thawed) 142.9 454. 0,174 H.B.S. (thawed) 142.9 454. 1,124 Subgrade 179.0 3,-73.1	86         54,4         67,68         10,0         kPa         1,840         ,32           23         46,9         57,74         10,0         kPa         1,820         ,31           85         73,6         113,47         12,0         kPa         1,840         ,33           18         113,3         272,17         13,0         kPa         1,840         ,33           28         153,1         528,65         13,0         kPa         1,840         ,32           15         184,6         J <sub>1</sub> =75,48          1,055         ,38
Targential Strain   Eq. (10w pressure):   13 Peb   13 Ner   13 Ner   13 Ner   13 Ner   14 Ner   14 Ner   14 Ner   15 Ner   14 Ner   15 N		253.2	566.6		•
0.050 Asphalt Cencrete 6602.0 6.6° 2.320 .40 0.250 H.B.S. (thawed) 40.5 50.63 44.8 61.33 7.4 kFz 1.820 .33 0.300 H.B.S. (thawed) 42.6 58.77 38.1 46.31 6.9 kFz 1.820 .33 0.300 H.B.S. (thawed) 42.6 58.77 38.1 46.31 6.9 kFz 1.820 .33 0.350 H.B.S. (thawed) 42.6 58.77 38.1 46.31 6.9 kFz 1.820 .33 0.350 H.B.S. (thawed) 55.3 170.16 46.4 115.24 2.4 kFz 1.800 .33 0.400 H.B.S. (thawed) 89.8 95.95 70.3 289.10 2.4 kFz 1.800 .33 0.174 H.B.S. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 0.174 H.B.S. (thawed) 8		Hr J <sub>2</sub> /T <sub>OCT</sub>	or  H <sub>F</sub> J <sub>2</sub> /τ <sub>oct</sub> Ψ τ <sub>d 1</sub> μ <sub>r</sub>	$J_2$ = second stress invertent tension, $\gamma_d$ = dry unit weigh	, Toct = octahedral shear stress, e = mois t, ur = resilient Poisson's ratio
0.300 H.3.5. (thawed) 42.6 58.77 38.3 46.31 6.9 kFz 1.820 .33 (5) Negative normal etresses and strains are compressive. 0.305 H.3.5. (thawed) 55.3 170.36 46.4 115.22 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.400 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 89.8 495.95 70.3 289.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.2 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains are compressive. 0.174 H.3.5. (thawed) 55.3 2.10 2.4 kFz 1.800 .33 (5) Negative normal etresses and strains	0.050 Asphalt Cencrete 0.250 H.B.S. (thawed)	6602.0 40.5 50.63	6602.0 6.6" 2.320 .40 44.8 63.33 7.4 kPm 1.820 .33	•	
30 Oct 13 Peb 6 Mar 13 Mar 21 Mar 28 Mar 4 Apr 24 Apr 7 May 29 May 25 Jul 27 Sept 20 Nov  c <sub>c</sub> (low pressure): 4.791x10 <sup>-4</sup> 2.279x10 <sup>-6</sup> 3.146x10 <sup>-4</sup> 2.608x10 <sup>-4</sup> 3.264x10 <sup>-4</sup> 2.425x10 <sup>-4</sup> 2.989x10 <sup>-4</sup> 4.894x10 <sup>-4</sup> 9.620x10 <sup>-4</sup> 9.348x10 <sup>-4</sup> 7.415x10 <sup>-4</sup> 4.051x10 <sup>-4</sup> 2.901x10 <sup>-4</sup> (high pressure): 9.789x10 <sup>-4</sup> 4.253x10 <sup>-6</sup> 6.446x10 <sup>-4</sup> 4.542x10 <sup>-4</sup> 6.759x10 <sup>-4</sup> 4.936x10 <sup>-4</sup> 6.539x10 <sup>-4</sup> 9.975x10 <sup>-4</sup> 1.948x10 <sup>-3</sup> 1.936x10 <sup>-3</sup> 1.500x10 <sup>-3</sup> 8.365x10 <sup>-4</sup> 5.987x10 <sup>-4</sup>	0.350 H.B.S. (thawed) 0.400 H.B.S. (thawed) 0.1/4 H.B.S. 1.524 Subgrade	55.3 170.36 89.8 495.95 127.1 1068.11 180.6 J <sub>1</sub> =-72.25	46.4 115.24 2.4 kPa 1.800 .33 70.3 289.10 2.4 kPa 1.800 .33 99.2 617.14 2.4 kPa 1.800 .33 181.9 J <sub>1</sub> =-74.76 1.055 .35	(5) Negative normal etresses and	strains are compressive.
c <sub>t</sub> (low pressure): 4.791x10 <sup>-6</sup> 2.279x10 <sup>-6</sup> 3.146x10 <sup>-4</sup> 2.608x10 <sup>-6</sup> 3.264x10 <sup>-6</sup> 2.425x10 <sup>-6</sup> 2.989x10 <sup>-6</sup> 4.894x10 <sup>-6</sup> 9.620x10 <sup>-6</sup> 9.348x10 <sup>-6</sup> 7.415x10 <sup>-6</sup> 4.051x10 <sup>-6</sup> 2.901x10 <sup>-6</sup> (high pressure): 9.789x10 <sup>-6</sup> 4.253x10 <sup>-6</sup> 6.446x10 <sup>-6</sup> 4.542x10 <sup>-6</sup> 6.759x10 <sup>-6</sup> 4.936x10 <sup>-6</sup> 6.539x10 <sup>-6</sup> 9.975x10 <sup>-6</sup> 1.946x10 <sup>-3</sup> 1.936x10 <sup>-3</sup> 1.500x10 <sup>-3</sup> 8.365x10 <sup>-6</sup> 5.987x10 <sup>-6</sup>			•		
(high pressure): 9.789x10 <sup>-4</sup> 4.253x10 <sup>-6</sup> 6.446x10 <sup>-4</sup> 4.542x10 <sup>-4</sup> 6.759x10 <sup>-4</sup> 4.936x10 <sup>-4</sup> 6.539x10 <sup>-4</sup> 9.975x10 <sup>-4</sup> 1.948x10 <sup>-3</sup> 1.906x10 <sup>-3</sup> 1.500x10 <sup>-3</sup> 8.365x10 <sup>-4</sup> 5.987x10 <sup>-4</sup>	ε <sub>ε</sub> (low pressure):				
	•				

Table D3b. Resilient moduli and supporting data calculated by NELAPAV for Hart Brothers test section, 1980.

25 February 1980 (Day 56)			26 March 1980 (Day 86)	
Plate Pressure (kPa).	279.0	6US,U (*C)	Plate Pressure (kPs): 240.0	414.0 T(*C)
Thickness (m) Haterials	Hr J2/1sct (MPa) (kPa)	or $\frac{H_T}{T} = \frac{J_2/T_{OCT}}{T_{OCT}} = \frac{V_T}{T_0} = \frac{V_T}{T_0}$ (HPa) (HPa) (Mg/m <sup>3</sup> )	Thickness $T$ $J_2/\tau$ oct $T$ $J_2/\tau$ oct $T$ $T$	or  Mr J <sub>2</sub> /foct \$\psi\$ Td \$\psi\$ \$\frac{\psi}{d}\$ \$\psi}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi}\$ \$\psi\$ \$\frac{\psi}{d}\$ \$\psi\$ \$\psi\$ \$\psi}\$ \$\psi\$ \$\psi}\$ \$\psi\$ \$\psi}\$ \$\psi\$ \$\ps
0.050 Asphalt Concrete 0.250 H.B.S. (frozen) 0.000 H.B.S. (frusen) 0.224 H.B.S. (thawed) 0.700 H.B.S. 1.524 Subgrade Subgrade	12168.0 670.4 39.44 281.1 13.01 42.5 221.35 79.2 876.02 179.9 J <sub>1</sub> =-67.97 200.0	12168.03* 2.320 .35 793.3 62.556* 1.584 .30 446.8 42.283* 1.584 .30 37.4 107.42 1.0 kPs 1.715 .33 65.2 569.77 1.0 kPs 1.715 .33 176.7 J = 70.05 1.055 .35 200.0 1.055 .35	0.050 Aaphalt Concrete 6353,U 0.250 H.B.S. (thawed) 19.8 78,75 0.300 H.B.S. (trowed) 43.1 81.78 0.224 H.B.S. (trowen) 244.8 66.89 U,700 H.B.S. (trowen) 244.8 55.76 1.524 Subgrade 173.0 J <sub>1</sub> =69.27 - Subgrade 200.0	6353.0 9.0" 2.320 .45 22.9 108.97 0.0 kPa 1.851 .33 42.4 79.02 5.0 kPa 1.800 .33 188.9 32.87 -1" 1.584 .30 53.7 371.72 1.0 kPa 1.715 .33 176.1 J <sub>1</sub> =70.75 7- 1.055 .35 200.0 1.055 .35
12 March 1980 (Day 72)			29 March 1980 (Day 89)	
Plate Pressure (kPa):	255.0		Plate Pressure (kPs): 262.0	360.0 **T(*C)
Thickness (m) Materials	H <sub>T</sub> J <sub>2</sub> /T <sub>oct</sub> (NPa)	$\frac{M_r}{r}$ $\frac{J_2/\tau_{oct}}{J_2}$ $\frac{v}{\tau_d}$ $\frac{V_d}{r}$ $\frac{V_d}{(MPa)}$ $\frac{V_d}{(MPa)}$	Thickness $\frac{H}{r}$ $\frac{J_2/\tau}{oct}$ oct $\frac{(w)}{r}$ Haterials $\frac{HPa}{r}$ $\frac{J_2/\tau}{oct}$	$\frac{H}{\epsilon}$ $\frac{J_2/\tau_{oct}}{\text{(MPa)}}$ $\frac{\Psi}{\text{(kPa)}}$ $\frac{V_d}{\text{(kPa)}}$ $\frac{\mu_{\epsilon}}{\text{(kPa)}}$
0.050 Asphalt Concrete 0.250 H.B.S. (frozen) 0.300 H.B.S. (frozen) 0.224 H.B.S. (thawed) 0.700 H.B.S. 1.524 Subgrade Subgrade	7001.0 122.5 11.39 100.3 6.54 35.4 171.54 65.2 666.02 170.7 J <sub>1</sub> ==68.06 200.0	7001.0 7.7° 2.320 .40 180.8 29.161° 1.584 .30 218.4 48.891° 1.584 .30 31.8 125.01 0.0 kPs 1.715 .33 53.7 397.65 0.0 kPs 1.715 .33 174.5 J <sub>1</sub> =70.48 1.055 .35 200.0 1.055 .35	0.050 Aaphalt Concrete 6644.U 0.250 H.B.S. (thawed) 20.0 80.83 0.300 H.B.S. (thawed) 45.8 59.16 0.224 H.B.S. (thawed) 42.7 142.79 U.700 H.B.S. (thawed) 62.6 487.35 1.524 Subgrade 174.8 J <sub>1</sub> -70.23 - Subgrade 200.0	6644.0 8.4" 2.320 .65 21.6 97.79 0.0 kPa 1.651 .33 43.6 53.09 9.0 kPa 1.820 .53 39.8 122.25 3.0 kPa 1.750 .33 36.5 388.40 2.0 kPa 1.750 .35 177.5 J <sub>1</sub> =-71.04 1.055 .35 200.0 1.055 .35
19 March 1980 (Day 79)			3 April 1980 (Day 94)	
Flate Pressure (kPs):	266.0	382.0 T(*C) or	Plate Pressure (kPa): 252.0	351.0 T(*C)
Thickness (m) Materials	H J <sub>2</sub> /1 <sub>oct</sub> (MPa) (kPa)	$\frac{M_r}{r}$ $\frac{J_2/\tau_{oct}}{\sqrt{MPe}}$ $\frac{\Psi}{\sqrt{MPe}}$ $\frac{J_2}{\sqrt{MPe}}$ $\frac{\Psi}{\sqrt{MPe}}$ $\frac{J_2}{\sqrt{MPe}}$ $\frac{\Psi}{\sqrt{MPe}}$	Thickness T J2/Toct (m) Materials (MPa) (MPa)	
0.050 Asphalt Concrete 0.250 H.B.S. (thawed) 0.300 H.B.S. (frozen) 0.224 H.B.S. (frozen) 0.700 H.B.S. 1.524 Subgrade Subgrade	5431.0 23.1 111.25 249.7 70.62 208.5 41.55 73.6 506.77 173.8 J <sub>1</sub> =-68.46 200.0	5431.0 — 11.1° 2.320 .45 26.1 165.90 0.0 kpc 1.651 .33 237.7 61.71 -1.1° 1.384 .30 170.4 24.79 -1.1° 1.584 .30 65.3 389.99 2.0 kpc 1.750 .33 175.1 J <sub>1</sub> =-9.36 — 1.055 .35 200.0 — 1.055 .35	0.050 Asphalt Concrete 5232.0 — 0.250 B.3.5. (theored) 27.6 67.08 0.300 B.3.5. (theored) 45.2 53.48 0.700 B.3.5. (theored) 42.3 144.35 0.700 B.3.5. (theored) 42.3 151.99 1.524 Subgrade 17.5.4 3 2-70.00 m Subgrade 200.0	42.4 46.32 10.0 kPa 1.820 .33 39.2 122.34 4.0 kPa 1.750 .33 56.8 406.37 1.5 kPa 1.715 .33
22 March 1980 (Day 82)			10 April 1980 (Day 101)	
Plate Pressure (kPa):	197.0		Plate Pressure (kPs): 247.0	354.0 T("C)
Thickness (m) Materials	H J2/Toct (HPa) (kPa)	or  H	Thickness $\frac{M}{r}$ $\frac{J_2^{/\tau}}{\cot(kPa)}$ (kPa) (kPa)	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
0.050 Asphalt Concrete 0.250 R.B.S. (thawed) 0.300 H.B.S. (thawed) 0.224 H.B.S. (thawed) 0.700 H.B.S. 1.524 Subgrade Subgrade	8958.0 18.4 67.17 40.6 71.57 45.0 171.79 67.6 603.41 173.4 J <sub>1</sub> -69.57 200.0	8958.U 4.4° 2.320 .4U 10.9 89.U2 U.O kPa 1.651 .33 37.4 59.07 5.0 kPa 1.850 .33 39.2 128.73 2.0 kPa 1.750 .33 55.6 400.28 1.0 kPa 1.715 .33 175.2 J <sub>1</sub> =70.87 1.055 .35 200.0 1.055 .35	0.050 Asphalt Concrete 5078.0 0.250 H.B.S. (thawed) 25.6 57.80 0.300 H.B.S. (thewed) 33.3 58.92 0.224 H.B.S. (thewed) 37.3 145.86 0.700 H.B.S. 60.4 515.97 1.524 Subgrade 174.0 J = 70.35	31.6 52.55 7.0 kPa 1.780 .33 36.3 122.00 0.0 kPa 1.750 .33 53.7 397.88 0.0 kPa 1.715 .33
			Plate Freesure (kPa): 238.0	331.0 T(*C)
			Thickness r $J_2/\tau_{\rm oct}$ (w) Materials (NPs) (kPs)	or r J <sub>2</sub> /T <sub>oct</sub> \$\psi\$ \gamma_d  \begin{array}{ccc} \psi & \gamma_d & \begin{array}{ccc} \psi & \psi & \end{array} \\ (\mathbf{MPa}) & (\mathbf{MPa}) & (\mathbf{MPa}) & \end{array}
			0.050 Asphalt Concrete 4028.U 0.250 H.B.S. (thered) 20.9 62.92 0.300 H.B.S. (thered) 41.9 57.64 0.224 H.B.S. (thered) 49.6 142.12 0.700 H.B.S. 74.6 523.14 1.524 Subgrade 175.1 J <sub>1</sub> =-70.97 5ubgrade 200.U	4028.U 15.1" 2.320 .45 28.6 /2.29 1.0 kPs 1.730 .33 39.9 51.79 9.0 kPs 1.800 .33 46.0 120.53 4.0 kPs 1.780 .33 66.8 410.74 2.0 kPs 1.780 .33

Notes: (1) Hoduli, stresses, and strains calculated by NELAPAV

(2)  $M_r$  = resilient modulus,  $J_1$  = first stress invariant or bulk stress,  $J_2$  = second stress invariant,  $\tau_{oct}$  = octahedral shear excess,  $\phi$  = moisture temsion,  $\tau_d$  = dry unit weight,  $\mu_r$  = resilient Poisson's ratio

(3)  $M_{_{\rm F}}$  and  $J_{_{\rm 2}}/\tau_{_{\rm oct}}$  are calculated at r=0 and center of respective layer

(4) H.B.S. refers to Hart Brothers sand (never frozen except as noted)

(5) Negative normal stresses and strains are compressive.

#### Tangential Strain $g_{\epsilon}$ (r = 0, z = .05) and Vertical Strain $g_{\phi}$ (r = 0, z = 1.524)

25 Feb 12 Mer 19 Mer 22 Mer 26 Mer 29 Mer 3 Apr 10 Apr 17 Apr 1.0 Apr 1.7 Apr 4.151ki0<sup>-6</sup> 3.763ki0<sup>-6</sup> 3.763ki0<sup>-6</sup> 3.371ki0<sup>-6</sup> 3.591ki0<sup>-6</sup> 3.700ki0<sup>-6</sup> 3.843ki0<sup>-6</sup> 4.151ki0<sup>-6</sup> 3.612ki0<sup>-6</sup> 3.612ki0<sup>-6</sup> 3.083ki0<sup>-6</sup> 3.083ki0<sup>-6</sup> 3.639ki0<sup>-6</sup> 3.643ki0<sup>-6</sup> 3.643ki0<sup>-6</sup> 3.643ki0<sup>-6</sup> 3.683ki0<sup>-6</sup> 3.683

# Table D4a. Resilient moduli and supporting data calculated by NELAPAV for Hyannis sand test section, 1979.

11 October 1978 (May -64) Plate Pressure (hPa):	<u> </u>	,5		512.4	r(*c)			23 April 1979 (Day 113) Plate Pressure (kPa):	25	8.7		542.0	T(*C)		
Thickness Materials	Я <sub>р</sub> (ИРа)	J <sub>2</sub> / Tuck (kPa)	H <sub>r</sub> (HFa)	J <sub>2</sub> / t <sub>uct</sub> (kPa)	* (%Pa)	() (Nu/m²)	<b>"</b> ,	Thickness	H r (HPa)	J <sub>2</sub> / <sub>Toct</sub> (kPa)	H <sub>r</sub> (MPa)	J <sub>2</sub> /t <sub>oct</sub> (kPs)	or ♦ (kPa)	γ <sub>d</sub> 3,	¥t
0.050 Ampinit Concrete 0.250 H.B. (thewed) 0.300 H.B. (thewed) 0.200 H.B. (thewed) 0.200 H.B. (thewed) 0.200 H.B. (thewed) 0.424 H.B. 1.524 Subgrade Bubgrade	7551.0 62.2 63.9 82.3 100.2 123.7 126.1 200.0	50.90 50.45 147.41 364.73 804.23 168.72	7551.0 69.0 60.0 72.6 86.4 103.5 123.9 200.0	75,27 44,47 93,02 207,06 410,63 160,53	4.0" B.U kYa B.U kYa B.U kYa b.U kYa	2, 120 1, 690 1, 690 1, 690 1, 670 1, 670 1, 655	.40 .30 .30 .30 .40 .40 .40 .35	0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.200 H.S. (thawed) 0.424 H.S. 1.324 Subgrade  Subgrade	936.0 64.5 57.7 76.7 94.0 116.4 125.5 200.0	68.64 38.80 131.99 285.40 553.80 166.50	936.0 70.6 53.6 70.9 83.9 101.1 123.5 200.0	96.62 29.41 97.95 185.40 376.34 158.96	28.4° 6.0 kPa 7.8 kPa 6.0 kPa 6.0 kPa 6.0 kPa	1.690	.50 .40 .35 .40 .40 .40 .35
12 February 1979 (Day 43) Plate Pressure (kPa):	273.	.1		547.5	Ť(*C) of			7 May 1979 (Day 127) Plate Pressure (kPa):	26	3.3		539.3			
Thickness (m) Heterials	H <sub>e</sub> (HPa)	J2 <sup>/ T</sup> oct (kPa)	H <sub>r</sub> (MPa)	J <sub>J</sub> /Toct (kPa)	(kPa)	<sup>γ</sup> d (Μ <sub>Μ</sub> /m <sup>3</sup> )	ν <sub>ε</sub>	Thickness	H <sub>c</sub> .	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / τ <sub>oct</sub>	T(*C) or ∳	Ya .	μχ
0.050 Asphalt Concrete 0.250 H.S. (frosen) 0.300 H.S. (frosen) 0.300 H.S. (frosen) 0.300 H.S. (frosen) 0.404 H.S. 1.524 Bubgrads Subgrads		- 1	15135-U 29993-9 17448-4 447-1 21-0 161-U 123-1 20U-U		-9.0° -8.7° -4.7° -1.0° 0.0° 8.0 kPa	2.320 1.366 1.366 1.366 1.366 1.690 1.055	.30 .30 .30 .30 .35 .35	(m) Materials  0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.200 H.S. (thawed) 0.424 H.S. 1.524 Subgrade  Subgrade	(HPa) 437.0 63.3 60.4 75.2 93.5 116.7 125.7 200.0	(kPa) 	(HPa) 437.0 70.1 58.9 68.9 63.4 101.7 122.8 200.0	98.98 45.01 79.56 166.20 352.06 156.37	34.9*	2.320 1.670 1.670 1.690 1.690 1.690 1.055 1.055	.50 .40 .40 .35 .35 .35 .35
7 March 1979 (Day 66) Place Pressure (kPs):	261.	<u> </u>		366.6	T(*C)			29 May 1979 (Day 149) Plate Pressure (kPa):	27	.0		557.1	T(*C)		
Thickness (m) Materials	H <sub>E</sub> .	J <sub>2</sub> / t <sub>oct</sub> (kPs)	H <sub>T</sub> (HPa)	J <sub>2</sub> / t <sub>oct</sub> (kPa)	or •	<sup>Y</sup> d (H <u>u</u> /≡ <sup>3</sup> )	ν <sub>e</sub>	Thickness (a) Materials	H <sub>r</sub> (MPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	H <sub>r</sub> (HPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	or •	<sup>Ү</sup> d (не/я <sup>3</sup> )	u <sub>r</sub>
0.050 Asphalt Concrete 0.130 M.S. (frosen) 0.300 M.S. (frosen) 0.300 M.S. (thawed) 0.200 H.S. (thawed) 0.200 H.S. (thawed) 0.424 M.S. 1.524 Subgrade Subgrade 12 March 1979 (Day 71)	7835.0 21.0 21.0 79.0 94.7 115.9	125.67 249.87 538.09	7835.0 21.0 21.0 73.6 84.2 99.9 120.3 200.0	  96.01	4.0° 0.0° 0.0° 8.0 kPa 8.0 kPa 8.0 kPa	2.320 1.366 1.366 1.690 1.690 1.690 1.055	.40 .30 .30 .35 .35 .35 .35	0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.200 H.S. (thawed) 0.424 H.S. 1.524 Subgrade  Subgrade	571.0 62.3 58.7 72.8 89.5 111.0 123.7 200.0	67.95 47.84 122.71 267.58 605.48 159.65	571.0 68.9 56.9 67.5 80.3 97.0 123.2 200.0	 99.52 42.63 92.11	32.7° 4.0 kPs 6.0 kPs 4.0 kPs	2.320 1.670 1.670 1.670 1.670 1.670 1.670 1.055	.50 .40 .40 .40 .40 .40 .35
Plate Pressure (kPa):	271.	.0		572.1	T(*C)			24 July 1979 (Day 205) Plate Pressure (kPa):	27	.0		579.0	T("C)		
Thickness (m) Haterials	H <sub>r</sub> (NPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPs)	H <sub>C</sub> (HPa)	J <sub>2</sub> / t <sub>oct</sub> (kPa)	or # (kPa)	Y <sub>d</sub> (Ng/m <sup>3</sup> )	u <sub>r</sub>	Thickness (m) Materials	K <sub>r</sub> (NPa)	J2 <sup>/T</sup> oct (kPa)	Mr (MPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	ot •	Υ <sub>d</sub> (Hg/m <sup>3</sup> )	u <sub>r</sub>
0.050 Amphalt Concrete 0.100 H.S. (frozen) 0.450 H.S. (frozen) 0.300 H.S. (frozen) 0.200 H.S. (frozen) 0.424 H.S. 1.524 Subgrade Subgrade		    1252.68 154.81	7299.0 21.0 1966.8 1085.1 21.0 124.1 122.4 200.0	695.67 155.13	5.1° 0.0° -0.4° -0.2° 0.0° 8.0 kPa	2,320 1,366 1,366 1,366 1,366 1,690 1,055	.40 .30 .30 .30 .35 .35	0.050 Asphalt Concrete 0.250 H.S. (thewed) 0.300 H.S. (thewed) 0.300 H.S. (thewed) 0.200 H.S. (thewed) 0.474 H.S. 1.524 Subgrade  Subgrade	416.0 67.7 58.4 75.9 94.7 118.4 125.6 200.0	106.50 47.17 107.85 250.40 581.76 166.88	416.0 76.7 56.8 69.0 83.8 102.0 123.5 200.0		35.3° 2.0 kPa 6.0 kPa 8.0 kPa 8.0 kPa	2.320 1.650 1.670 1.690 1.690 1.690 1.055	.50 .45 .40 .35 .35 .35 .35
20 March 1979 (Day 79) Plate Pressure (kPa):	261.	.4		547.5				27 September 1979 (Day 270)	<u>.</u>						
		J <sub>Z</sub> / <sub>Toct</sub>	H,	J <sub>2</sub> / t <sub>oct</sub>	T(°C)	v	h	Plate Pressure (kPa):	280	0.6		596.8	T(°C)		
(m) Haterials	(MPa)	(kPa)	(MPa)	(kPa)	(kPa)	(Hg/m <sup>3</sup> )	<sup>в</sup> с	Thickness (m) Materials	M r (MPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	Η <sub>τ</sub> (HPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	•	γ <sub>d</sub> (Hg/m <sup>3</sup> )	"r
0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (trozen) 0.200 H.S. (thawed)	1976.0 67.6 72.5 1085.1	92.40 106.57	1976.0 78.0 78.4 1085.1	158.79 143.80	-0.2°	2.320 1.670 1.670 1.366 1.690	.50 .40 .40 .30	0.050 Amphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed)	936.0 68.4 56.8 74.5	110.85 46.34 143.31	936.0 77.1 55.3 70.4		28.4° 2.0 kPa	2.320	.50 .45 .40 .45
0.424 H.S. 1.524 Subgrade Subgrade	125.0	351.06 714.78 156.73	93.1 109.0 123.4 200.0	233.90 426.05 158.62	8.0 kPa 8.0 kPa 		.35 .35 .35	0.300 H.S. (thawed) 0.200 H.S. (thawed) 0.424 H.S. 1.524 Subgrade Subgrade	92.6 116.0 125.3 200.0	229.74 539.43 165.49	92.6 (16.0 (25.3 200.0	115.79 145.45 310.57 157.25	8.0 kPa	1.650	.35 .35 .35
1.524 Subgrade Subgrade  27 March 1979 (Day 86)	125.0 122.9	714.78 156.73	109.0 123.4 200.0	426.05	8.0 kPa  	1.690	. 35	0,200 H.S. (thaved) 0,424 H.S. 1,524 Subgrade	116.0 125.3 200.0	539,43 165,49 	116.0 125.3 200.0	145.45 310.57 157.25	3.0 kPa 8.0 kPa 8.0 kPa	1.650 1.690 1.690 1.055	.35
1.524 Subgrade Subgrade 27 March 1979 (Day 86) Plate Pressure (kPa):	125.0 122.9 200.0	714.78 156.73	109.0 123.4 200.0	426.05 158.62 	8.0 kPs   T(*C) or	1.690 1.055 1.055	. 35	0.200 H.S. (thawed) 0.324 H.S. 1.324 Subgrade = Subgrade 19 Hovember 1979 (Day 323) Plate Pressure (kPa):	116,0 125,3 200,0	539,43 165,49 	116.0 125.3 200.0	145,45 310,57 157,25	3.0 kPa 8.0 kPa 8.0 kPa 	1.650 1.690 1.690 1.055 1.055	.35
1.524 Subgrade  27 March 1979 (Day 86)  Plate Pressure (kPa):  Thicknees (a) Materials  0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.200 H.S. (thawed) 0.200 H.S. (thawed) 0.404 H.S. (thawed) 0.404 H.S. Subgrade  Subgrade	122.9 200.0 261. Hr (MPa) 5945.0 65.5 61.8 78.7 97.2 120.6	714.78	109.0 123.4 200.0	426.05 158.62 547.5 J <sub>2</sub> /T <sub>oct</sub> (kPa)	T(*C) or + (kPa)	1,690 1,055 1,055 1,055 Y <sub>d</sub> (Hg/m <sup>3</sup> ) 2,320 1,670	.35	0,200 H.S. (thaved) 0,424 H.S. 1,524 Subgrade	116.0 125.3 200.0	539,43 165,49 	116.0 125.3 200.0	145.45 310.57 157.25 589.9 J <sub>2</sub> /τ <sub>oct</sub> (kPe) 77.11 42.97 88.89 174.36	3.0 kPa 8.0 kPa 8.0 kPa  T(*C) or	1.650 1.690 1.690 1.055	.35
1.524 Subgrade  Subgrade  Subgrade  Subgrade  Plate Pressure (kPa):  Thickness (a) Materials  0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.424 H.S. 1.524 Subgrade  Subgrade  Subgrade  3 April 1979 (bay 93)	125,0 122,9 200,0 261. H <sub>r</sub> (NPa) 5945,0 65.5 61.8 78.7 97.2 120.6 125.8	714.78 156.73 156.73 .4 (kPa) 22.15 64.05 124.30 2275.89 625.43 167.51	M <sub>r</sub> (NPa) 5945.0 73.1 60.8 71.6 86.0 104.3 122.1 200.0	426.05 158.62 	8.0 kPe  T(*C) or  (kPa) 8.1* 4.0 kPa 8.0 kPa  T(*C)	Y <sub>d</sub> (Mg/m <sup>3</sup> )  2.320 1.670 1.690 1.690 1.690 1.690	.35 .35 .35 .45 .40 .40 .35 .35 .35	0,200 H.S. (thoused) 0,224 H.S. 1,524 Subgrade  19 Hovember 1979 (Day 323)  Plate Pressure (kPa):  Thickness (m) Materials 0,030 Asphalt Concrete 0,230 H.S. (thoused) 0,300 H.S. (thoused) 0,300 H.S. (thoused) 0,400 H.S. (thoused) 0,424 H.S. 1,524 Subgrade	16.0 125.3 200.0 27 H <sub>r</sub> (#ra) 6334.0 66.8 67.7 86.1 101.8 121.5 126.2 200.0	3.7 2/ toct (kPa) 	H <sub>E</sub> (103) 200.0 H <sub>E</sub> (100-a) 6334.0 64.3 77.1 64.3 77.9 99.5 104.5 123.1 200.0	145,45 310,47 157,25 259,9 J <sub>2</sub> / T <sub>0</sub> ct (kFa) -77,11 42,97 86,89 174,36 362,79 157,55	3.0 kPa 8.0 kPa 8.0 kPa T(*C) or \$\phi\$ (kPa) 7.2* 12.0 kPa 12.0 kPa 12.0 kPa 10.0 kPa 8.0 kPa	1.650 1.690 1.690 1.055 1.055 1.055 2.320 1.710 1.710 1.690 1.690 1.055	.35 .35 .35 .35 .35 .35 .35 .35 .35
1.524 Subgrade  Subgrade  Subgrade  Subgrade  27 March 1979 (Dey 86)  Plate Pressure (kPa):  Thickness (m) Materials  0.050 Asphalt Concrete  0.250 H.5. (thawed)  0.300 H.5. (thawed)  0.200 H.5. (th	125.0 122.9 200.0 261. Hr (MPa) 5945.0 65.5 61.8 78.7 97.2 120.6 125.8 200.0	714.78 156.73 156.73 .4 (kPa) 22.15 64.05 124.30 2275.89 625.43 167.51	M <sub>r</sub> (NPa) 5945.0 73.1 60.8 71.6 86.0 104.3 122.1 200.0	426.05 158.62 547.5 J <sub>2</sub> /T <sub>oct</sub> (RPa) ————————————————————————————————————	8.0 kPs  T(*C) or  (kPs) 8.1* 8.0 kPs 8.0 kPs  T(*C) or  0	Y <sub>d</sub> 3) (Ng/m <sup>3</sup> ) 2.320 1.670 1.690 1.650 1.055	.35 .35 .35 .45 .40 .40 .35 .35 .35	0,200 H.S. (thoused) 0,224 H.S. 1.521 Subgrade 19 November 1979 (Day 323) Plate Pressure (kPa):  Thickness (a) Materials 0.050 Asphalt Concrete 0.250 H.S. (thoused) 0.300 H.S. (thoused) 0.300 H.S. (thoused) 0.200 H.S. (thoused) 0.200 H.S. (thoused) 0.424 H.S. 1.524 Subgrade  Subgrade  Notes: (1) Moduli, stree (2) H <sub>p</sub> = resili J <sub>2</sub> = second	116.0 125.3 200.0 27 Rg (WPa) 6334.0 66.8 67.7 86.1 101.8 121.5 126.2 200.0	519.45 165.49 3.7 (kPa) 	/ (16.0 125.3 200.0 // (187a) 6334.0 75.1 64.3 77.9 89.5 104.5 123.1 200.0	145.45 310.47 157.25 589.9 J <sub>2</sub> /r <sub>oct</sub> (kPs) 77.11 42.97 88.69 174.36 362.79 157.55	3.0 kPa 5.0 kPa 5.0 kPa T(*C) or (kPa) 7.2* 12.0 kPa 12.0 kPa	1.650 1.690 1.095 1.055 1.055 Y <sub>d</sub> (H <sub>B</sub> /= <sup>3</sup> ) 2.320 1.710 1.710 1.710 1.710 1.690 1.695 1.055	.40 .35 .35 .40 .35 .35 .35 .35 .35
1.524 Subgrade Subgrade Subgrade Subgrade 27 March 1979 (Day 86) Plate Pressure (kPa):  Thickness (s) Materials 0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.400 H.S. (thawed) 0.404 H.S. (thawed) 0.424 H.S. (thawed)	125.0 122.9 200.0 261. H <sub>F</sub> (NPa) 5945.0 65.5 61.8 78.7 97.2 120.6 125.8 200.0	714.78 156.73 .4 .4 .2 .7 .82.15 .82.15 .82.15 .82.15 .82.15 .82.15 .82.15 .82.15 .82.15 .83.15	H <sub>r</sub> (MPa) 5945.0 73.1 60.8 60.0 104.3 122.1 200.0 104.3 122.1 200.0 104.2 122.1 200.0	426.05 158.62 547.5 J <sub>2</sub> /T <sub>oct</sub> (kPa) ————————————————————————————————————	T(*C) or (kPa) 8.1* 4.0 kPa 4.4 kPa 8.0 kPa 8.0 kPa T(*C) or (kPa) 6.6* 4.0 kPa 8.0 kPa 8.0 kPa 8.0 kPa	Y <sub>d</sub> 1,055  Y <sub>d</sub> 1,055  Y <sub>d</sub> (Mg/m <sup>3</sup> ) 2,320 1,670 1,690 1,690 1,055 1,055 1,690 1,695 1,055	.45 .40 .40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35	0,200 H.S. (thoused) 0,224 H.S. 1.524 Subgrade 19 November 1979 (Day 323) Plate Pressure (kPa):  Thickness (a) Materials 0,050 Asphalt Concrete 0,250 Asphalt Concrete 0,250 Asphalt Concrete 0,250 H.S. (thoused) 0,300 H.S. (thoused) 0,424 H.S. 1,524 Subgrade  Subgrade  Notes: (1) Modeli, stree (2) H <sub>r</sub> = resili J <sub>2</sub> = second tension, v <sub>d</sub> (3) H <sub>r</sub> and J <sub>2</sub> /v <sub>0</sub> (4) H.S. refere (5) Negative nor	166.0 125.3 200.0  27  H <sub>c</sub> (rea) 6334.0 68.8 97.7 86.1 101.8 121.5 126.2 200.0  ent moduli stress i = d ry un ct are ca	519.45 165.49  J2/toct (LPa)  55.42 52.15 129.72 233.65 642.83 168.97  because calculated at a wand (new sees and attentions.	16.0   125.3   200.0   H <sub>c</sub>   (100a)   6334.0   75.1   64.3   77.9   89.5   104.5   123.1   200.0   ullated by   ret stresoct oct oct oct	145.45 310.47 157.25 157.25 157.25 157.25 157.25 17.11 42.97 88.69 174.36 362.79 1174.36 362.79 1175.35 1181.42 1181.4	T(°C)  T(	1.650 1.690 1.690 1.055 1.055 1.055 1.055 1.055 1.710 1.710 1.710 1.690 1.690 1.055 1.055	.35 .35 .35 .35 .35 .35 .35 .35 .35 .35
1.524 Subgrade  "Subgrade  "Subgrade  27 March 1979 (Day 8b)  Plate Pressure (kPa):  Thickness (m) Materials  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.300 H.S. (thawed)  0.200 H.S. (thawed)  0.200 H.S. (thawed)  1.524 Subgrade  Subgrade  Subgrade  3 April 1979 (Day 93)  Plate Pressure (kPa):  Thickness (m) Materiale  0.050 Asphalt Concrete  0.250 H.S. (thawed)  1.524 Subgrade  3 April 1979 (Day 93)  Plate Pressure (kPa):  Thickness (m) Materiale  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.300 H.S. (thawed)  0.300 H.S. (thawed)  0.300 H.S. (thawed)  0.424 H.S.  1.524 Subgrade  Subgrade	125.0 122.9 200.0  261.  Hr (NPa) 5945.0 65.5 61.8 78.7 77.2 120.6 125.8 200.0  249.  Hr (NPa) 6602.0 65.1 61.7 79.4 98.1 121.9 125.9 200.0	714.78 156.73 	Nr (MPa) 5945.0 73.1 60.8 71.6 86.0 104.3 122.1 200.0 104.3 122.1 200.0 104.2 122.1 200.0 17.7 86.0 104.2 122.1 200.0 Tang	426.05 158.62 158.62  547.5  J <sub>2</sub> /Toct (RFa) 124.25 60.11 86.82 173.60 153.90  551.6  J <sub>2</sub> /Toct (RFa) 125.09 81.04 86.94 173.28 359.18 153.82 gential St	T(*C) or (kPa) 8.1* 4.0 kPa 4.4 kPa 8.0 kPa 8.0 kPa 7(*C) or (kPs) 6.6* 4.0 kPa 8.0 kPa 8.0 kPa 8.0 kPa	Y <sub>d</sub> (M <sub>B</sub> /m <sup>3</sup> ) 2.320 1.670 1.690 1	.45 .40 .40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35	0.200 H.S. (thoused) 0.224 H.S. 1.521 Subgrade 19 Evember 1979 (Day 323) Plate Pressure (hPa):  Thickness (s) Materials 0.050 Asphalt Concrete 0.250 H.S. (thoused) 0.300 H.S. (thoused) 0.300 H.S. (thoused) 0.200 H.S. (thoused) 0.200 H.S. (thoused) 0.424 H.S. 1.524 Subgrade  Notes: (1) Moduli, stres (2) H <sub>F</sub> = resili J <sub>2</sub> = second tension, v <sub>d</sub> (3) M <sub>T</sub> and J <sub>2</sub> /v <sub>o</sub> (4) H.S. refers (5) Negative nor and Vertical Strain s <sub>y</sub> (r	166.3 125.3 200.0  27  H <sub>E</sub> (rea) 6334.0 638.8 67.7 86.1 101.8 121.5 126.2 200.0  126.5 12	519.45 165.49  J2/toct (LPs)  55.42 52.15 129.72 233.65 166.97  betains calculated at a sand (new sees and att 1.524) 29 May	(16,0)   (125,	145.45 310.47 157.25 157.25 157.25 157.25 158.99 17.11 42.97 88.89 174.36 362.79 157.55 WELAPAV Is invaria ahedral e 1ient Poid	T("C) or (LPa) T("C) or (LPa) T, 2" 12.0 kPs 12.	1.650 1.690 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055	.40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35
1.524 Subgrade  Subgrade  Subgrade  Subgrade  27 March 1979 (Day 86)  Plate Pressure (kPa):  Thickness (e) Materials  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.300 H.S. (thawed)  0.300 H.S. (thawed)  0.424 H.S. (thawed)  3 April 1979 (Day 93)  Plate Pressure (kPa):  Thickness (e) Materiale  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.100 Asphalt Concrete  0.250 H.S. (thawed)  0.300 H.S. (thawed)  0.424 H.S.  1.524 Subgrade  Et (low pressure):	125.0 122.9 200.0  261.  Hr (NPa)  5945.0 65.5 61.8 78.7 97.2 120.6 125.8 200.0  249.  Mr (NPa)  6602.0 65.1 61.7 79.4 98.1 121.9 125.9 200.0	714.78 156.73  156.73  156.73  27 Toct (kPa)  167.51  167.51  167.51  17.51  180.25  65.06  650.87  180.09  12.899x10	H <sub>r</sub> (MPa) 5945.0 73.1 60.8 711.6 86.0 104.3 122.1 200.0 Tany 7 Mai 6 3.461x	426.05 158.62  158.62  J <sub>2</sub> /T <sub>oct</sub> (kFa)  124.25 60.11 86.82 173.60 153.90  251.6  J <sub>2</sub> /T <sub>oct</sub> (kFa) 123.09 61.04 86.94 173.28 359.18 153.82  gential Si 17.18 10 <sup>-6</sup> 3.36:10 <sup>-6</sup>	8.0 kPa  T(*C) or (kPa)  8.1* 4.0 kPa 4.4 kPa 8.0 kPa  T(*C) or (kPa)  T(*C) or t (kPa)  T(*C) or t (kPa)  T(*C) or t (kPa)  6.6*  4.0 kPa 8.0 kPa	Y <sub>d</sub> (N <sub>B</sub> /m <sup>3</sup> ) 2.320 1.670 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.670 1.690 1	.45 .40 .40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35	0,200 H.S. (thoused) 0,224 H.S. 1.524 Subgrade  19 Hovember 1979 (Day 323)  Plate Pressure (kPa):  Thickness (a) Haterials 0.050 Asphalt Concrete 0,230 H.S. (thoused) 0.300 H.S. (thoused) 0.424 H.S. 1.524 Subgrade  (2) H <sub>T</sub> = resilit J <sub>2</sub> = second tension, v <sub>d</sub> (3) H <sub>T</sub> and J <sub>2</sub> /v <sub>o</sub> (4) H.S. refers (5) Negative nor and Vertical Strain c <sub>w</sub> (r  3 Apr 23 Apr	116.0 125.3 200.0  27  Hg (HPa)  6334.0 66.8 67.7 86.11 101.8 121.5 126.2 200.0  seen, and seent moduli etrese i dry un unter are cato Hyanni mal strese - 0, g - 7 Hay 5.495x10	519.45 165.49  J2/Tect (tPs)	16.0   125.3   200.0   M <sub>E</sub>   (100m)   6334.0   75.1   77.9   89.5   104.5   123.1   200.0   ulated by   rret stresoct = oct	145.45 310.47 157.25 157.25 157.25 157.25 157.25 177.11 42.97 88.69 174.36 362.79 157.55 EXTLAPAV is invaria abedral a lient Poir center of a except a	T(*C) or (kPe) 7.2° (kPe) 12.0 kPe 12.0	1.650 1.690 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055	.40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35
1.524 Subgrade  Subgrade  Subgrade  Subgrade  27 March 1979 (Dey 86)  Plate Pressure (kPa):  Thickness (w) Materials  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.200 H.S. (thawed)  0.200 H.S. (thawed)  0.200 H.S. (thawed)  7.204 Subgrade  Subgrade  Subgrade  Subgrade  Materials  1.524 Subgrade  Materials  0.050 Asphalt Concrete  0.250 H.S. (thawed)  0.424 H.S.  Thickness (w) Materials  0.050 Asphalt Concrete  0.550 Asphalt Concrete  0.250 H.S. (thawed)  0.250 H.S. (thawed)  0.250 H.S. (thawed)  0.300 H.S. (thawed)  0.300 H.S. (thawed)  0.300 H.S. (thawed)  0.424 H.S. (thawed)  0.250 H.S. (thawed)  0.424 H.S. (thawed)  0.424 H.S. (thawed)  0.425 H.S. (thawed)  0.426 H.S. (thawed)  0.426 H.S. (thawed)  0.427 H.S. (thawed)  0.428 H.S. (thawed)  0.429 H.S. (thawed)  0.420 H.S. (thawed)	125.0 122.9 200.0  261.  H <sub>r</sub> (NPa) 5945.0 65.5 61.8 78.7 97.2 120.6 125.8 200.0  249.  H <sub>c</sub> (NPa) 6602.0 65.1 61.7 79.4 98.1 121.9 125.9 200.0  31 Oct 1.955x10 <sup>-6</sup> 4.625x10 <sup>-6</sup>	714.78 156.73  156.73  156.73  27 Toct (kPa)  124.30 167.51  167.51  180.25 65.30 128.30 128.30 128.30 128.30 128.30 128.00 128.00 128.00 128.00 128.00 138.99x10  13.899x10	H <sub>r</sub> (NPs) 5945.0 73.1 60.8 71.6 86.0 104.3 122.1 200.0 73.2 60.6 71.7 86.0 104.3 122.1 200.0 73.2 60.6 71.7 8.0 73.8 60.6 71.7 8.0 71.7 8	426.05 158.62  158.62  347.5  J <sub>2</sub> /T <sub>oct</sub> (kPa)  124.25 60.11 86.82 173.60 153.90  125.09 61.04 86.94 173.28 359.18 153.82  mential St  110 <sup>-4</sup> 7.100 <sup>-4</sup> 7.100 <sup>-4</sup>	T(*C) or (kPa)  8.1* 4.0 kPa 4.0 kPa 8.0 kPa 8.0 kPa  T(*C) or (kPa)  T(*C) or 4 0 kPa  T(*C) or 4 0 kPa	Y <sub>d</sub> (Ng/m <sup>3</sup> ) 2.320 1.670 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.690 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.670 1.690	.40 .40 .40 .40 .40 .40 .40 .40 .40 .40	0.200 H.S. (thoused) 0.224 H.S. 1.521 Subgrade 19 Evember 1979 (Day 323) Plate Pressure (hPa):  Thickness (s) Materials 0.050 Asphalt Concrete 0.250 H.S. (thoused) 0.300 H.S. (thoused) 0.300 H.S. (thoused) 0.200 H.S. (thoused) 0.200 H.S. (thoused) 0.424 H.S. 1.524 Subgrade  Notes: (1) Moduli, stres (2) H <sub>F</sub> = resili J <sub>2</sub> = second tension, v <sub>d</sub> (3) M <sub>T</sub> and J <sub>2</sub> /v <sub>o</sub> (4) H.S. refers (5) Negative nor and Vertical Strain s <sub>y</sub> (r	116.0 125.3 200.0  27  Mr (197a)  6334.0 68.8 67.7 86.1 101.8 121.5 126.2 200.0 200.0 200	539.45 165.49 J <sub>2</sub> /7 <sub>oct</sub> (kPa) 55.42 52.15 129.72 233.65 642.83 168.97 strains calciant, to the light, 1culated at a seas (new sees and att) 29 May 6.437x10 1.212x10	16.0   125.3   200.0   125.3   200.0   125.3   126.3   15.3   15.3   15.3   16.3   17.9   89.5   104.5   104	165.45 310.57 157.25 157.25 157.25 157.25 157.25 157.25 177.11 42.97 88.89 174.36 362.79 157.55  EXAPAV IN INVARIAN INVA	3.0 kPa 8.0 kPa 8.0 kPa 7.2° (LPa) 7.2° 12.0 kPa 12.0 kPa	1.650 1.690 1.690 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.055 1.710 1.710 1.710 1.690 1.690 1.055 1.055 1.055 1.055 1.055 1.055 1.055	.40 .35 .35 .35 .35 .35 .35 .35 .35 .35 .35

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Table D4b. Resilient moduli and supporting data calculated by NELAPAV for Hyannis sand test section, 1980.

25 February 1980 (Day 56	<u>.)</u>							29 March 1980 (Day 89)							
Place Prossuce (kPa)	2	113		550	T(*c)			Plate Pressure (kPa).		255	4	99	<b>t</b> (*c)		
Thickness (m) Haterials	M <sub>r</sub> (MPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	HPa)	J <sub>2</sub> /r <sub>oct</sub> (kPa)	or † (kPa)	<sup>Y</sup> d (Hg/ <del>m³</del> )	u r	Thickness (m) Materials	H <sub>T</sub>	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	H F (MPa)	J <sub>2</sub> /T <sub>oct</sub>	or •	γ <sub>d 3</sub> (Hg/m )	۴,
0,050 Asphalt Concrete 0.250 N.S. (frozen) 0,300 H.S. (thawed) 0,300 H.S. (thawed) 0,500 H.S. (thawed) 1,524 H.S. (thawed) 5,524 Subgrade 6 Subgrade	7377.0 1996.8 68.9 92.4 128.0 125.6 200.0	130.30 227.89 775.03 166.77	7377.0 1996.8 67.6 83.4 111.3 124.6 200.0	121.67 154.83 460.29 162.95	8.0 kJ	2,320 1,366 2a 1,650 2a 1,690 2a 1,690 1,055 1,055	.40 .30 .45 .35 .35 .35	0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 N.S. (thawed) 0.624 H.S. 1.524 Subgrade	5350.0 63.5 59.5 72.2 99.4 124.7 200.0	73.01 50.47 155.89 523.94 163.51	5350.0 70.8 59.5 68.4 89.0 123.0 200.0	110.12 50.39 127.22 344.22 157.19	11.3° 4.0 kP 6.0 kP 0.0 kP	2.320 a 1.670 a 1.670 a 1.650 a 1.650 1.055 1.055	.45 .40 .40 .45 .45
12 March 1980 (Day 72)								3 April 1980 (Day 94)							
Place Pressure (kPa):	2	40	56	0	T(*c)			Plate Pressure (kPs):		248		466	T(*C)		
Thickness (m) Materials	H r (HPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	H <sub>r</sub> (H2Pa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	or † (kPa)	Y <sub>d</sub> (Hg/=³)	u,	Thickness (m) Materials	Н <sub>Г</sub> (нр <sub>я</sub> )	3 <sub>2</sub> /τ oct (kPa)	H r (HPa)	J <sub>2</sub> /τ 2 oct (kPa)	or # (kPa) (	<sup>7</sup> d Mg/m <sup>3</sup> )	٧,
0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 W.S. (frozen) 0.300 H.S. (thawed) 0.624 H.S. 1.524 Subgrade Subgrade	8190.0 85.6 1996.8 83.8 119.5 122.7 200.0	297.37 273.98 602.47 156.56	8190.0 104.8 1996.8 78.3 102.5 121.3 200.0	211,40 368.03 151.23	0.4° 0.0 k	2.320 Pa 1.366 1.366 Pa 1.366 Pa 1.690 1.055	.40 .45 .30 .45 .35 .35	0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.624 H.S. 1.524 Subgrade Subgrade	2388.0 62.1 58.3 71.5 99.3 124.8 200.0	67.05 69.22 150.56 521.81 163.58	2388.0 67.9 58.2 67.3 88.7 123.8 200.0	94.07 68.76 119.39 340.45 157.08	22.1° 4.0 kP4 0.0 kP4 0.0 kP4	1.650	.50 .40 .45 .45 .45 .35
19 March 1980 (Day 79) Place Pressure (kPa)	3	397	55	2	τ(*c)			10 April 1980 (Day 101) Plate Pressure (kPs).		226	47	s	T(*C)		
Thickness (w) Materials	Н г (жРа)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	Н г (НР4)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	or † (kPa)	Υ <sub>d</sub> (Hg/m³)	μ <sub>τ</sub>	Thickness (m) Haterials	H <sub>r</sub>	J <sub>Z</sub> /†oct (kPa)	H <sub>F</sub> (HPa)	J <sub>2</sub> /τ oct (kPa)	or •	Yd Mg/m³)	۰,
0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.100 H.S. (thawed) 0.100 H.S. (thawed) 0.400 H.S. (tozen) 0.624 H.S. 1.524 Subgrade  Subgrade	5116.0 76.8 72.2 589.7 106.0 123.6 200.0	196.69 118.94  383.79 159.31	5116.0 82.2 74.9 589.7 100.3 122.8 200.0	255.24 136.67 310.52 156.28	4.0 ki	2,320 Pa 1.650 Pa 1.670 1.366 Pa 1.690 1.055	.45 .45 .40 .30 .35 .35	0.050 Asphalt Concrete 0.250 H.S. (thuwed) 0.300 H.S. (thuwed) 0.300 H.S. (thuwed) 0.624 H.S. 1.524 Subgrade  Subgrade	4747.0 65.0 59.1 75.1 104.7 124.9 200.0	104.72 72.78 181.16 636.69 164.13	4747.0 72.5 53.9 68.0 98.1 122.9 200.0	158 63 51.63 124.46 344.95 156.94	0.0 kPs 0.0 kPs 0.0 kPs 0.0 kPs	1.650	.45 .45 .45 .45 .45 .35
f 27 March 1980 (Day 92)								17 April 1980 (Day 108)							
Place Pressure (kPa)		146		516	r(*c)			Plate Pressure (kPs):		221	43	9	T(*C)		
Thickness (m) Materials	비 <sub>문</sub> (연안4)	J <sub>2</sub> /r <sub>oct</sub> (kPa)	H r (MPa)	J <sub>2</sub> /† oct (kPa)	or # (kPa)_	<sup>Y</sup> d (Hg/m <sup>1</sup> )	ν <sub>τ</sub>	Thickness (a) Materials	н <sub>г</sub> (неа)	J <sub>2</sub> /Toct (kPa)	H F (HPa)	J <sub>2</sub> /t <sub>oct</sub>	or • (kPa) (	Yd 3	۴,
0.050 Asphalt Consider 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (thawed) 0.624 H.S. 1.524 Subgrade Subgrade	8958.0 65.9 60.2 75.0 105.0 125.2 200.0	96 . 14 59 . 77 180 .02 4 34 .02 165 . 29	8958.0 76.6 59.7 67.4 88.1 122.7 200.0	170.46 57.98 122.93 223.10 155.99	4.0 k	2.320 Pa 1.650 Pa 1.670 Pa 1.670 1.055 1.055	.40 .45 .40 35	0.050 Asphalt Concrete 0.250 H.S. (thewed) 0.300 H.S. (thewed) 0.300 H.S. (thewed) 0.624 N.S. 1.524 Subgrade  Subgrade	1583.0 62.0 57.9 72.2 101.4 123.7 200.0	58.92 67.53 156.22 564.79 159.63	1583.0 68.0 57.6 67.3 89.4 122.4 200.0	83.70 66.08 119.64 350.41 154.93	0.0 kP	2.320 1.670 1.650 1.650 1.650 1.055	.50 .40 .45 .45 .45 .35
26 March 1980 (Day 86)															
Place Pressure (kPa)		244	48	37	T(*C)			4 Notes: (1) Moduli, st							
Thickness (s) Naterials	H <sub>r</sub> (HPa)	J <sub>2</sub> /† oct (kPa)	H T (HPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	or † (kPa)	Υ <sub>d</sub> (Hg/m³)	۴,	•	d stress	slus, J <sub>i</sub> = fi: invariant, <b>p</b> son's ratio					ght,
0.050 Asphalt Concrete 0.250 H.S. (thawed) 0.300 H.S. (thawed) 0.300 H.S. (frozen) 0.624 H.S. 1.524 Subgrade	5595.0 65.8 61.6 73.3 104.7 124.1 200.0	73.89 57.43 165.27 485.03 161.11	5595.0 72.4 59.8 68.8 92.0 122.3 200.0	105.96 51.46 129.97 297.48 154.59	6.0 k	2.320 Pa 1.670 Pa 1.670 Pa 1.670 L.055 1.055	.40 .35 .40 .35	<ul> <li>(3) M<sub>T</sub> and J<sub>1</sub></li> <li>(4) H.S. refer</li> <li>(5) T<sub>OFT</sub> = ort</li> <li>(6) Negative n</li> </ul>	e to Hyan ahedral e	ints eand	(kfa)		live layer		

#### Tangential Strain $c_{\xi}$ (r = 0, z = .05) and Vertical Strain $c_{\psi}$ (r = 0, z = 1.524)

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	25 Feb	12 Mar	19 Mar	22 Mar	26 Mar	29 Mar	3 Apr	10 Apr	17 Apr
ε <sub>t</sub> (low pressure):	7.302×10 <sup>-6</sup>	1.580x10-4	3.940x10-4	1.601x10 <sup>-4</sup>	2.516x10 <sup>-4</sup>	2.744m10 <sup>-4</sup>	3.892x10 <sup>-4</sup>	2.575m10 <sup>-4</sup>	4.082m10 <sup>-4</sup>
(high pressure):	1.439x10 <sup>-5</sup>	3.386x10 <sup>-4</sup>	5.310x10-4	4.027x10-4	4.852×10 <sup>-4</sup>	5.138x10 <sup>-4</sup>	6.985x10 <sup>-4</sup>	5.209×10-4	7.670x10 <sup>-4</sup>
$\epsilon_{\psi}(\text{low pressure})$ :	-1.658x10 <sup>-4</sup>	-1.619±10 <sup>-4</sup>	-1.982x10-4	-1.781x10 <sup>-4</sup>	-1.828x10-4	-1.902x10 <sup>-4</sup>	-1.898±10 <sup>-4</sup>	-1.848x10 <sup>-4</sup>	-1.834x10 <sup>-4</sup>
(hich pressure):	-1.918+10-4	-1-971=10-4	-2 -203=10 <sup>-4</sup>	-2.402-10-4	-2-275-10-4	-2 .360+10 <sup>-4</sup>	-2 336-10-4	-2 330-10-4	-2 249-10-4

o Secon∎posesson variates = pessesson properties = posesson essesson = Vecon∎posesson variates = pessesson = posesson =

October 1978 (Day 63	<u>-</u>															
ate Pressure (kPa).		259		547	T(*C)			Plate i	ressure (kPa).		253	- 55	4	T(*C)		
	н,	J <sub>2</sub> /t <sub>oct</sub>	я	J <sub>2</sub> /t <sub>oct</sub>	or •	Y a	ν <sub>r</sub>	Thickne		Hr	J <sub>2</sub> /T <sub>oct</sub>	H	J <sub>2</sub> /r <sub>oct</sub>	or •	۲ <sub>4</sub>	μ
ickness (m) Materials	(HPa)	(kPa)	(MPa)	(kPa)	(kPa) (H	g/m³)	_	<u>(m)</u>	Haterials	(HPa)	(kP4)	(HPa)	(kPa)	( <u>k</u> Pa) (	Mg/e <sup>3</sup> )	
050 Asphalt Concrete 250 D.G.S. (thawed)	100.8	83.09	6349.0 107.3	131.82	10.0 kPa	2.100	.40 .40	0.250	Asphalt Concret D.G.S. (thawed	90.8	67.31	782.0 96.9	108.43	30.0° 6.0 kPa		
300 D.G.S. (thaved) 300 D.G.S. (thaved)	97.2 103.7	63.66 178.77	94.8 98.3	52.93 121.08	10.0 kPa :	2.100 1.970	.40 .40	0.300	D.G.S. (thawed) D.G.S. (thawed)	94.0	49.81 190.69	84.5 90.4	39.78 143.87	6.0 kPa 0.0 kPa	1.970	. 4
300 D.G.S. (thawed) 324 D.G.S.	118.1 132.8	464.47 1102.40	109.9 122.4	273.60 604.58	6.0 kPa 6.0 kPa	1.970	.40 .40	0.324	D.G.S. (thawed) D.G.S.	141.5	408.40 1010.43	116.2	236.72 536.97	10.0 kPa 10.0 kPa	2.100	.4
524 Subgrade = Subgrade	130.3	185.12	128.0 200.0	175.81		1.055 1.055	.35	1.524	Subgrade Subgrade	132.3 200.0	193.42	130.3 200.0	185.05		1.055	
February 1979 (Day 4	3)							7 Hay 1	979 (Day 127)							
ate Pressure (kPa):		264	554		-/			Plate f	ressure (kPa):		264	55	4	t(*c)		
				. ,	t(°C)								1 /-	or		
ickness (m) Materials	nr (HPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	H <sub>E</sub> (HPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)		Y d g/m³)	"r	Thickne		H <sub>E</sub> (HSPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	H <sub>r</sub> (HPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	(kPa) (i	Yd Mg/m³)	
050 Asphalt Concrete			14382.0			2.320	.30	0.050	Asphalt Concret	e 421.0		421.0			2.320	
250 D.G.S. (frozen) 300 D.G.S. (frozen)	32664.0		32664.0 12543.0		-6.5° -2.0°	1.800	. 30	0.250	D.G.S. (thaved) D.G.S. (thaved)	95.5 82.1	56.04 70.62	101.5 82.0	87.54 70.09	10.0 kPa 0.0 kPa	2.100	.4
300 D.G.S. (frozen) 300 D.G.S. (frozen)	3395.0		3395.0 1101.0		-0.4*	1.800 1.800	. 30 . 30	0.300	D.G.S. (thawed) D.G.S. (thawed)	93.6	184.96 393.72	90.2 116.1	141.73 235.12	0.0 kPa 10.0 kPa	1.970	.4
324 D.G.S. 524 Subgrade	159.2 130.4	4190.89 185.71	145.8 129.9	2192.83 183.56	6.0 kPa	1.970	.40	0.324	D.G.S. Subgrade	140.8 132.6	972.02 194.48	129.8 130.6	534.59 186.17	10.0 kPa	1.055	
Subgrade	200.0		200.0			1.055	. 35		Subgrade	200.0		200.0			1.055	.3
March 1979 (Day 66)									1979 (Day 149)				***			
ate Pressure (kPa):		268	572	2	τ(*c)			Plate P	ressure (kPa):	<u>'</u>			763	T(°C)		
	Ħ,	J <sub>2</sub> /t <sub>oct</sub>	He	J <sub>2</sub> /T <sub>oct</sub>	or •	۲ <sub>d</sub>	μ <sub>τ</sub>	Thickne		HF	J <sub>2</sub> / <sub>Toct</sub>	H <sub>r</sub>	J <sub>2</sub> /τ <sub>oct</sub>		۲ <sub>d</sub>	¥
ickness (m) Materials	(HP.a)	(kPa)	(HPa)	(kPa)		g/ <del>g</del> 3)		(a)	Materials	(NPa)	(kPa)	(MPa)	(kPa)		Hg/m³ )	
D50 Asphalt Concrete 250 D.G.S. (thawed)	7589.0 89.0	127.95	7589.0 95.8	219.58	4.5° 0.0 kPa		.40 .45	0.050	Asphalt Concret D.G.S. (thawed)	90.6	66.91	550.0 96.7	107.23	6.0 kPa		.4
300 D.G.S. (thawed)	83.0 92.8	76.47 174.72	82.8 89.0	75.25 127.67	0.0 kPs 0.0 kPs	1.970	.45 .45	0.300	D.G.S. (thewed) D.G.S. (thewed)	85.9	51.16 182.73	83.7 94.8	42.52 137.63	5.0 kPa 3.0 kPa	1.970	.4
300 D.G.S. (thawed) 300 D.G.S. (thawed)	105.6 129.7	449.43 926.27	99.0 119.6	280.26 510.45	0.0 kPa 6.0 kPa	1.970	.45	0.300	D.G.S. (thewed) D.G.S.		400.18 990.11	116.0 129.6	233.67 529.66	10.0 kPa 10.0 kPa	2.100	.4
324 D.G.S. 524 Subgrade • Subgrade	131.1	188.31	127.9	175.43			.35	1.524	Subgrade Subgrade	132.3	193.26	130.2	184 .85			
	200.0		100.0			1.033	,		1979 (Day 206)							
Harch 1979 (Day 71)		.14							ressure (kPa):	-	274	58	2			
ste Pressure (kPa):		274	<del></del>	378	T(°C)									T(*C) or		
ckaese	×r	J <sub>2</sub> /t <sub>oct</sub>	H <sub>E</sub>	J <sub>2</sub> /T <sub>oct</sub>		٧,	u <sub>e</sub>	Thickne	44	H <sub>E</sub>	J <sub>2</sub> /τ <sub>oct</sub>	H <sub>E</sub>	J <sub>2</sub> /τ <sub>oct</sub>	(10-1)	۲ <sub>۵</sub> سـرگ	
(m) Materials	(ICPa)	(křa)	(HPa)	(Ma)		<u>( ( fa</u>		( <u>a)</u>		(HFa)	(kPa)	(HPa) 201.0	(kPa)		Mg/m³) 2.320	
050 Asphalt Concrete 050 D.G.S. (thawed)	7251.0 89.1	129.48	7251.0 95.9	220.91	5.2° 0.0 kPa	2.320 1.970	.40 .45	0.250	Asphalt Concret D.G.S. (thaved) D.G.S. (thaved)	97.5	65.43 52.10	104 . 2 85 . 7	106.57 43.99	10.0 kPa 6.0 kPa	2.100	
300 D.G.S. (thaved) 300 D.G.S. (thaved)	82.9 92.7	75.84 172.32	82.7 88.9	74 .81 126 .88	0.0 kPa 0.0 kPa	1.970		0.300	D.G.S. (thewed) D.G.S. (thewed)	100.2	182.02 393.29	96.6 116.0	139.03 234.24	4.0 kPa 10.0 kPa	1.970	٠. ١
300 D.G.S. (theored) 324 D.G.S.	105.3 129.4	442.10 909.56	98.9 119.5	278.31 506.27	0.0 kPa 4.0 kPa	1.970	.45 .40	0.324	D.G.S. Subgrade	140.6 132.6	962.30 194.45	129.5	525.21 185.94	10.0 124		
524 Subgrade - Subgrade	131.0 200.0	188.13	12 <b>8.9</b> 200.0	179.69		1.055 1.055	.35 .35		Subgrade	200.0		200.0		-	1.055	
March 1979 (Day 79)								27 Sept	ember 1979 (Day							
ate Pressure (kPa):		261	560		T(*C)			Plate 1	ressure (kPa):		276	59	7	T(*C)		
	H,	J <sub>2</sub> /T <sub>oct</sub>	H <sub>e</sub>	1 /•	or					H,	J <sub>2</sub> /T <sub>oct</sub>	H,	J <sub>2</sub> /T <sub>oct</sub>	or •	۲۵	,
ickness (m) Materials	r (1874)	(kPa)	(167a)	J <sub>2</sub> /T <sub>oct</sub> (kPa)		¥₄ a/=³)	- r	Thickne (m)		(10°a)	(hřa)	(MPa)	(kPa)	(kPa) (	Ng/e³)	
050 Asphalt Concrete	2054.0		2054.0		20.8*	2.320	.50		Asphalt Concret D.G.S. (thewed)		65.98	736.0 103.9	104.32		2.320	
250 D.G.S. (thawed) 300 D.G.S. (thawed)	87.9 81.5	117.24 67.05	94.7 81.1		0.0 kPa . 0.0 kPa	1.970	.45 .45	0.300	D.G.S. (thawed) D.G.S. (thawed)	86.4	53.62 183.07	84 .4 96 .6	44.99 138.51	5.0 kPa 4.0 kPa	1.970	٠. ١
300 D.G.S. (thawed) 300 D.G.S. (thawed)	92.2 105.3	165.65 440.59	88.3 98.7	120.58 273.53	0.0 kPa 0.0 kPa	1.970	.45 .45		D.G.S. (thewed)		395.48 966.33	115.9 129.4	233.43 522.76	10.0 kPa	2.100	٠, ١
324 D.G.S. 524 Subgrade	129.7 131.1	925.81 188.39	119.5 129.0	506.92 179.84		1.055	.40 .35	1.524	Subgrade Subgrade	132.6	194.44	130.4	165.80	=	1.055	
- Subgrade	200.0		200.0	-		1.055	. 35		mber 1979 (Day							
March 1979 (Day 86) ate Pressure (kPa):		141	541						ressure (kPa):		:74		597			
ate Pressure (MPA):		261		<u>'</u>	T(*C)									T(°C)		
s c k neve	×,	J <sub>2</sub> /† oc t	H <sub>e</sub>	J <sub>2</sub> /T <sub>oct</sub>		۲d	ν <sub>e</sub>	Thickne		H <sub>T</sub>	J <sub>2</sub> /T <sub>oct</sub>	H <sub>F</sub>	J <sub>2</sub> /1 <sub>oct</sub>		Yd .	
(m) Materials	(MPa)	(kPa)	(HPa)	(kPa)	(kPa) (H	g/s³)		<u>(a)</u>	Materials	(HPa)	(kPa)	(MPa)	(kPa)		tg/w³ )	
050 Asphalt Concrete 250 D.G.S. (thawed)	3997.0 91.5	71,19	3997.0 94.4	112.39	13.3° 6.0 kPa		.45	0.250	Asphalt Concret D.G.S. (thawed)	99.9	78.23	5612.0 106.6	125.49	10.0 kPa		.4
300 D.G.S. (thaved) 300 D.G.S. (thaved)	82.7 92.9	74 .45 175 .21	82.4 89.0	72.72 128.18	0.0 kPa 0.0 kPa	1.970	.45 .45	0.300	D.G.S. (thawed) D.G.S. (thawed)	101.2	62.63 196.06	86.6 97.2	34 . 27 145 . 69	5.0 kPa 4.0 kPa	1.970	.4
100 D.G.S. (thaved) 124 D.G.S.	105.8	456.78 948.92	99.3 120.1	286 .40 527 .95	0.0 kPa 6.0 kPa	1.970	.45 .40	0.324	D.G.S. (thawed) D.G.S.	141.4	415.75 1003.94	116.6	242.65 538.98	10.0 kPs 10.0 kPs	2.100	.4
24 Subgrade Subgrade	131.2 200.0	188.60	129.2 200.0	180.11		1.055	. 35 . 35		Subgrade Subgrade	132.6 200.0	194 .62	130.5 200.0	186.06		1.055	
pril 1979 (Day 93)																
ce Pressure (kP4)		249		553												
			_		T(*C)			* Notes	(1) Moduli,				•			
kness	H r	J <sub>2</sub> /t <sub>oct</sub>	FI <sub>T</sub> (HOPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)		۲ <sub>۵</sub> (فه/ع	<b>"</b> r		(2) H <sub>T</sub> = rec		ulus, J <sub>i</sub> = fi Invariant, (					iehi
(m) Materials	(H(Pa) 5777.0		5777.0				.45				seon's ratio		·			
050 Asphalt Concrete 150 D.G.S. (thawed) 100 D.G.S. (thawed)	98.0 83.9	67.71 82.84	104.5	108,58	10.0 kPa 0.0 kPa	2,100	.40		(3) M <sub>r</sub> and .	J <sub>l</sub> are calc	ulated at r=0	and rente	r of respec	tive layer		
100 D.G.S. (thawed) 100 D.G.S. (thawed) 100 D.G.S. (thawed)	95.0 126.2	206.15 434.00	91.0 116.9	151.46	0.0 kPa 10.0 kPa	1.970	.45		(4) D.G.S.	refers to d	ense-graded s	tone				
190 D.G.S. (thaved) 124 D.G.S. 124 Subgrade	142.4	1058.80	130.5	556.29 186.63	10.0 kPa	2.100 1.055	.40		(5) tort * (	octahedral	shear stress	(kPa)				
Subgrade	200.0		200.0	100.07			.35		(b) Negative	normal st	resses and st	rains are	compressive			
ngential Strain et	(r = 0,	s = .05) as	od Vertical	Strain c.	(r = 0,	<u>• • 1.5</u>	324)									
	31 Oct	12 Feb	7 Mar	12 Mar	20 Na		7 Nac	3 Apr	23 Apr	7 May	29 May	24 Jul	27 8	ept l'	9 Nov	
	.082×10 <sup>-4</sup>	-1.880x10 <sup>-6</sup>		3.578±10	2.220m	10 4 2.	.705±10		4.153±10 <sup>-4</sup>	4.343x10	4.414=10	4.323E	10 4.28		. 31710	,-4
(low pressure): 2.																
(low pressure): 2. igh pressure): 4.				4	ر ا			4 ,	<b>→</b> →		4	4	4	4	.911x1	. ~

Table D5b. Resilient moduli and supporting data calculated by NELAPAV for dense-graded stone test section, 1980.

25 February 1980 (Day 56	<u>s)</u>						29 March 1980 (Day 89)							
Plate Pressure (kPa):		778		569	T(*C)		Place Pressure (kPa)		255	6	70	T(*C)		
Thickness (m) Haterials	H <sub>r</sub> (HPa)	J <sub>Z</sub> /t <sub>act</sub> (kPa)	H <sub>r</sub> (HPa)	J <sub>Z</sub> /t <sub>oct</sub> (kPa)	or Y <sub>d</sub> (kPa) (Mg/m³)	Ψ <sub>r</sub>	Thickness (m) Materials	H <sub>r</sub> (N(Pa)	J <sub>2</sub> /T <sub>oct</sub>	H <sub>c</sub> (HPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	•	Y <sub>d</sub> (Ng/s <sup>3</sup> )	<b>"</b> r
0.050 Asphalt Concrete 0.250 D.G.S. (thawed) 0.300 D.G.S. (frozen) 0.250 D.G.S. (frozen) 0.100 D.G.S. (frozen) 0.574 D.G.S. 1.524 Subgrade	5372.0 101.6 1934.0 1101.0 1101.0 145.6 130.8 200.0	246.13  1224.90 186.99	5372.0 110.9 1934.3 1101.0 1101.0 134.7 131.0 200.0	704 .44 188 .07	11.3° 2.320 0.0 kPa 1.970 -0.2° 1.800 -0.1° 1.800 -0.1° 1.800 10.0 kPa 2.100 1.055 1.055	.45 .30 .30 .30 .40	0.050 Asphalt Concrete 0.250 D.G.S. (thewed) 0.300 D.G.S. (thewed) 0.250 D.G.S. (thewed) 0.100 D.G.S. (thewed) 0.574 D.G.S. (thewed) 0.574 D.G.S. (thewed) 0.524 Subgrade	5310.0 91.4 89.4 112.1 119.4 127.1 132.0 200.0	81.08 68.49 136.39 290.23 798.47 192.22	5310.0 96.3 88.3 106.6 113.1 119.0 130.7 200.0	119.22 62.93 94.43 194.88 492.01 186.55	11.4* 5.0 kP 5.0 kP 12.0 kP 10.0 kP	2.320 a 1.970 a 1.970 a 2.100	.45 .40 .40 .35 .40 .40 .35
12 March 1980 (Day 72)							3 April 1980 (Day 94)							
Plate Pressure (kPa):		240	5;	25	r(*c)		Place Pressure (kPa):		259		48-	ti*ci		
Thickness (m) Heterials	H <sub>T</sub>	J <sub>2</sub> /τ oct (kPa)	H r (HPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	or † Y <sub>d</sub> (kPa) (Ng/a <sup>3</sup> )	ν <sub>Γ</sub>	Thickness (m) Materials	H r (MPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	H T (MPa)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	e e	ैत Ong⊹m <sup>8</sup> ⊥	٠,
0.050 Asphalt Concrete 0.250 D.G.S. (thewed) 0.300 D.G.S. (thewed) 0.250 D.G.S. (thewed) 0.100 D.G.S. (though) 0.104 D.G.S. (thewed) 0.574 D.G.S. 1.524 Subgrade  Subgrade	4819.0 89.5 90.5 1101.0 107.5 137.6 130.6 200.0	132.91 144.98  513.53 821.27 186.41	4819.0 97.4 94.8 1101.0 102.9 127.3 128.9 200.0	249.11 203.80 372.36 463.59 179.45	12.7° 2.320 0.0 kPa 1.800 0.0 kPa 1.800 -C.1° 1.800 0.0 kPa 1.800 10.0 kPa 2.100 1.055 1.055	.45 .45 .30 .45 .40	0.050 Asphalt Concrete 0.250 D.G.S. (thewed) 0.300 D.G.S. (thewed) 0.250 D.G.S. (thewed) 0.100 D.G.S. (thewed) 0.574 D.G.S. (thewed) 0.574 D.G.S. (thewed) 0.524 Subgrade	1415.0 90.0 87.8 108.8 110.7 126.3 131.9 200.0	72.08 60.20 126.95 289.90 762.71 191.44	1415.0 94.9 86.5 103.4 105.1 118.1 130.4 200.0	106 . 30 53 . 81 87 . 13 197 . 31 466 . 47 185 . 54	29.1° 5.0 kP 5.0 kP 11.0 kP 6.0 kP	2 320 a 1.970 a 1.970 a 2.100 a 1.970 a 1.970 L.055 L.055	.50 .40 .40 .35 .40 .40 .35
19 March 1980 (Day 79)							10 April 1980 (Day 101)							
Plate Pressure (kPa):		369	5	25	T(*C)		Plate Pressure (kPa):		241	49	11	T(*C)		
Thickness (m) Materials	H_F (NPA)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	H r (HPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	or † Y <sub>d</sub> (kPa) (Hg/m <sup>3</sup> )	u r	Thickness (m) Materials	H <sub>r</sub> (MPa)	J <sub>2</sub> /T <sub>oct</sub>	H r (MPa)	J <sub>2</sub> /t <sub>oct</sub> (kPs)	or •	<sup>T</sup> d (Mg/m³)	۰,
0.050 Asphalt Concrete 0.250 D.G.S. (thewed) 0.300 D.G.S. (thewed) 0.250 D.G.S. (frozen) 0.100 D.G.S. (frozen) 0.574 D.G.S. 1.524 Subgrade  ** Subgrade	2651.0 93.4 81.6 1934.0 1101.0 137.0 131.7 200.0	182.82 67.48 795.37 190.76	2651.0 96.7 81.9 1934.0 1101.0 132.7 131.1 200.0	235.14 69.72 628.52 188.32	20.8" 2.320 0.0 kPa 1.970 0.0 kPa 1.970 -0.2" 1.800 -0.1" 1.800 10.0 kPa 2.100 1.055 1.055	.45 .45 .30 .30 .40	0.050 Asphalt Concrete 0.250 D.G.S. (thawed) 0.300 D.G.S. (thawed) 0.250 D.G.S. (thawed) 0.100 D.G.S. (thawed) 0.574 D.G.S. 1.524 Subgrade  **Subgrade	4573.0 98.5 88.8 106.3 102.0 116.0 131.9 200.0	270.44 65.31 152.61 196.96 406.53 191.78	4573.0 104.2 86.8 100.6 96.4 107.7 130.2 200.0	407.49 55.55 101.47 104.29 236.49 184.88	5.0 kP 8.5 kP 6.0 kP	2.320 a 1.970 a 1.970 a 1.970 a 1.970 a 1.970 1.055 1.055	.45 .45 .40 .40 .40 .40
22 March 1930 (Day 82)							17 April 1980 (Day 108)							
Plate Pressure (kPa):	2	01		419	T(*C)		Flate Pressure (kPa):		:39	45	1	T(*C)		
Thickness (m) Materials	H r (HDa)	J <sub>2</sub> /r <sub>oct</sub> (kPa)	H <sub>T</sub> (HPa)	J <sub>2</sub> /t <sub>oct</sub> (kPa)	οτ Ψ γ <sub>d</sub> (kPa) (Ng/m <sup>3</sup> )	u ,	Thickness (m) Haterials	H <sub>r</sub> (HPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	H <sub>E</sub> (HDPa)	J <sub>2</sub> /τ <sub>oct</sub> (kPa)	† (kPa)	<sup>Y</sup> d ( <del>Ng/m<sup>3</sup> )</del>	٧ <sub>r</sub>
0.050 Asphalt Concrete 0.250 D.G.S. (thawed) 0.300 D.G.S. (thawed) 0.250 D.G.S. (thawed) 0.100 D.G.S. (thawed) 0.576 D.G.S. (thawed) 1.524 Subgrade  Subgrade	8958.0 87.6 88.5 112.1 122.6 140.6 133.3 200.0	114.31 72.83 182.68 350.88 963.78 197.50	8958.0 95.4 86.8 105.2 113.2 127.2 131.3 200.0	213.25 63.05 114.19 195.14 462.28 189.27	4.4° 2.320 0.0 kPs 1.970 4.0 kPs 1.970 10.0 kPs 2.100 10.0 kPs 2.100 10.0 kPs 2.100 1.055 1.055	.40 .45 .40 .40 .40 .40 .35	D.050 Asphalt Concrete 0.250 D.G.S. (thewed) 0.300 D.G.S. (thewed) 0.250 D.G.S. (thewed) 0.100 D.G.S. (thewed) 0.100 D.G.S. (thewed) 0.574 D.G.S. (thewed) 1.524 Subgrade	1798.0 91.0 87.5 108.3 101.6 115.6 131.9 200.0	68.21 58.90 141.23 338.57 875.31 191.46	1798.0 95.8 86.0 103.2 95.5 101.6 130.5 200.0	99.89 51.67 98.87 215.02 338.35 185.79	5.0 kP 10.0 kP 0.0 kP	2,320 a 1,970 a 1,970 a 2,100 a 1,970 a 1,970 1,055 1,055	.50 .40 .40 .40 .45 .45
26 March 1980 (Day 86)														
Place Pressure (kPa):		32	46	<u>s</u>	T(*C)		* Notes: (1) Moduli, m	itresses.	and strains	calculated	by NELAPAV			
Thickness (m) Haterials	H <sub>r</sub> (HPa)	J <sub>2</sub> /T <sub>oct</sub>	H T (HE's)	J <sub>2</sub> /T <sub>oct</sub> (kPa)	or † Y <sub>d</sub> (kPa) (Mg/m <sup>3</sup> )	ν <sub>τ</sub>	(2) N <sub>F</sub> = rest J <sub>2</sub> = sero	lient mod		irst stres	. invariant			ight,
0.050 Asphalt Concrete 0.250 D.G.S. (chawed) 0.300 D.G.S. (chawed) 0.250 D.G.S. (chawed) 0.100 D.G.S. (chawed) 0.574 D.G.S. (chawed) 0.574 Subgrade	4812.0 90.6 89.4 110.8 120.5 128.4 132.2 200.0	76.07 68.82 145.45 309.19 495.01 192.89	4812.0 96.1 88.0 104.7 113.2 119.1 130.7 200.0	117.11 63.39 95.67 195.34 494.62 186.67	11.3° 2.320 5.0 kPa 1.970 5.0 kPa 1.970 11.0 kPa 2.100 10.0 kPa 2.200 6.0 kPa 1.970 1.055	.45 .40 .40 .35 .40 .40	<ul> <li>(3) M<sub>r</sub> and J<sub>1</sub></li> <li>(4) D.G.S. re</li> <li>(5) τ<sub>ort</sub> ≠ or</li> </ul>	are main fers to d	ulated at re	U and rent stone (kPa)			er	

# Tangential Strain $e_{\xi}$ (r = 0, s = .05) and Vertical Strain $e_{\psi}$ (r = 0, s = 1.524)

25 Feb 12 Mar 19 Mar 22 Mar 26 Mar 29 Mar 3 Apr 10 Apr 17 Apr 1 Apr 22 Mar 2.085x10<sup>-6</sup> 2.265x10<sup>-6</sup> 4.306x10<sup>-6</sup> 1.433x10<sup>-6</sup> 2.183x10<sup>-6</sup> 2.282x10<sup>-6</sup> 3.806x10<sup>-6</sup> 2.233x10<sup>-6</sup> 3.256x10<sup>-6</sup> (high pressure): 4.092x10<sup>-6</sup> 4.748x10<sup>-6</sup> 5.888x10<sup>-6</sup> 3.461x10<sup>-6</sup> 4.253x10<sup>-6</sup> 4.112x10<sup>-6</sup> 6.853x10<sup>-6</sup> 4.433x10<sup>-6</sup> 5.942x10<sup>-6</sup> (high pressure): -1.771x10<sup>-6</sup>-1.904x10<sup>-6</sup>-1.995x10<sup>-6</sup>-1.922x10<sup>-6</sup>-1.943x10<sup>-6</sup>-1.978x10<sup>-6</sup>-1.988x10<sup>-6</sup>-1.973x10<sup>-6</sup>-1.977x10<sup>-6</sup> (high pressure): -2.008x10<sup>-6</sup>-2.332x10<sup>-6</sup>-2.150x10<sup>-6</sup>-2.392x10<sup>-6</sup>-2.307x10<sup>-6</sup>-2.313x10<sup>-6</sup>-2.348x10<sup>-6</sup>-2.384x10<sup>-6</sup>-2.335x10<sup>-6</sup>

# Table D6a. Resilient moduli and supporting data calculated by NELAPAV for Sibley till test section, 1979.

ACCORDED DE LA COMPANION DE LA

	30 October 1978 (Day -6	<u>3)</u>							23 April 1979 (Day 113)							
March   Marc	Plate Pressure (kPa):			47	12.2	- t(*c)			Plate Pressure (kPa):	2:	58.7	5	39.3	T(*C)		
Column   C		-		-		•	-			-				<b>0</b> Γ		4
Second column   Co	0.050 Asphalt Concrete		= _		12.64		2.320	.45	0.050 Asphalt Concrete	2596.0		2596.0		18.3*	2.320	
0.44 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	0.300 S.T. (though)	_	_	47.2	46.63	12.0 kPa	1.850	.35	0.300 S.T. (thawed)	44.8	67.24	44.3	63.59	8.0 Ma	1.850	.40
Column	0.624 S.T. 1.524 Subgrade		_	70.9 126.0	387.20	12.0 kPa	1.850	.35	0.624 S.T. (thawed)	76.5	576.47	69.0	336.47	12.0 kPa	1.850	. 35
Part		_	_	200.0		-	1.055				-			_		
Column																
This content	FIELE FRODUCTO (LPE):		1.0		90.0				Plate Pressure (kPs): _	27	1.0	5	59.8			
1	Thickness	N <sub>F</sub>	J <sub>2</sub> / t <sub>oet</sub>	HE	J <sub>2</sub> /t <sub>oct</sub>		<b>'</b>	ν <sub>E</sub>	Thickness	Hr	J <sub>2</sub> / τ <sub>oct</sub>	H <sub>E</sub>	J <sub>2</sub> / T <sub>oct</sub>		Yd	u <sub>t</sub>
0.00 0.1. (Freene					(kPa)					(Ma)	(kPa)			(LPa)	(Mg/m <sup>3</sup> )	
1.00   1.00	0.250 S.T. (freses)	8046.0		8046.0		-2.6*	1.890	.35	0.250 S.T. (thawed)	47.7	49.34	50.7	67.48			
Part	0.300 S.T. (fromen)	7641.0	_	7641.0	-	-2.4*	1.890	.35	0.300 S.T. (thawed)	55.2	146.28	51.7	103.37	10.0 kPa	1.850	. 35
Part	1.524 Subgrade	131.4		131.0			1.055	.35	1.524 Subgrade	128.3	176.96	126.7	170.96		1.055	.35
Part	6 March 1979 (Day 65)											200.0			,	.,,
Part	Plate Pressure (kPs):	25	5.9	52	9.7	7/10										
Martin   M		н	J_/+	×	1.7•	or			Flate Pressure (kPa):	261	.4	56	6.6			
Part   Column   Col									Thickness	H <sub>T</sub>	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / <sub>Toct</sub>		Y <sub>d</sub>	u <sub>t</sub>
0.000 5.11 (10-mars) 1.1	0.050 Asphalt Concrete	5819.0		5819.0		8.4*	2.320	.45	(m) Materials		(kPa)	(MPa)	(kPa)	(kPa)	(Hg/m <sup>3</sup> )	
Section   Control   Cont	0.300 S.T. (thewed)	37.1	84.63	37.0	84.20	0.0 kPa	1.900	.45	0.250 S.T. (thawad)	44.6	77.26	48.9	124.34	7.0 kPa	1.850	.40
Part   1975	0.624 S.T. (thewed)	55.5	689.91	50.6	428.07	0.0 kPa	1.900	.45	0.300 S.T. (thawed)	49.8	160.17	47.0	118.05	6.0 kPa	1.850	-40
Part									1.524 Subgrade	128.5	178.11	126.6	170.47		1.055	. 35
Part   Column   Col	12 March 1979 (Day 71)								_	100.0	_	200.0	_		1.055	. 33
Part	Place Pressure (kPs):	266	1.3	53	2.4	T(*C)			Plate Pressure (kPs):	280	.6	58	9.9			
Column   Materials   Column	***	H <sub>r</sub>	J <sub>2</sub> / Toct	H <sub>r</sub>	J <sub>2</sub> / †oct		Yd	μ			1./-			OT		
9-95 sphale Concrete 1881-0 18-20		(ICPs)	(kPa)	(IIPa)		(kPa)	(Hg/m <sup>3</sup>	)								Ψr
0.100 5.77. (Chemed) 2.71.   87.18   77.2   87.40   0.00 kPs   1.900   1.50   0.200 kPs   1.000   1.0	0.050 Asphalt Concrete 0.250 S.T. (thawed)				203.73				0.050 Asphalt Concrete		_					.50
123.6   123.	0.300 S.T. (thawed)	37.1	85.38	37.3	87.60	0.0 kPa	1.900		0.300 S.T. (thewed)	41.6	62.51	51.6 41.2	59.89	15.0 kPa 6.0 kPa	1.850 1.850	.35
Part   177   (by 78)   Fig.	1.524 Subgrade	128.8	179.10	126.1	168.59	_	1.055	.35	0.624 S.T. (thewad)	82.6	519.50	74.5	302.79	15.0 kPa	1.850	.35
Part   Presence (NFa)   Part		200.0		200.0		••	1.055	.35			- 1//.81					
This case   This		264	2	54	4.7					<u>n</u>						
Materials   (1970									Plate Pressure (kPa):	283	.3	59	6.8	T(*C)		
1960   1960									Thishman	×r	J <sub>2</sub> / t <sub>oct</sub>	H <sub>z</sub>	J <sub>2</sub> / t <sub>oct</sub>		γ.	u,
0.250 S.T. (thweel) 42.A 80.87					(kPa)						(kPa)			(kPa)	(Ng/m )	
0.300 S.T. (Channel) 52.2 150.35	0.250 S.T. (thawed)	42.4	80.87	46.1		5.0 kPa	1.850	.40	0.050 Asphalt Concrete : 0.250 S.T. (thawad)		91.29		146.14	8.0° 5.0 kPa		
1.526 Subgrades  120.0   17.44   125.7   167.12   -1.055 .35   1.05 .25   1.0	0.300 S.T. (thawed)	52.2	150.35	49.2	110-10	8.0 kPa	1.850	.40	0.300 S.T. (thawed)		72.89	41.4	71.57	5.0 kPa	1.850	-40
Plate Pressure (kPa)   246.4   547.5   7(°C) or		128.4	177.64	125.7		_	1.055	.35	1.524 Subgrade	128.4		126.2		15.0 kPa	1.850	.40 .35
Tickness	27 Herch 1979 (Day 86)									200.0	~	200.0	_		1.055	.35
No.   Process   No.   Process   Pr	Plate Pressure (kPa):	246	5.4	54	7.5	T(*C)				-						
Materiale (NPa)		Ħ.	J <sub>2</sub> / t <sub>oot</sub>	N,	J <sub>2</sub> / t <sub>nee</sub>	OT	Y <sub>4</sub>	ĸ.	Plate Pressure (kPa): _	273	.7	58	9.9			
0.250 S.T. (thermed) 43.9 83.13		_				(kfs)			Thickness	H <sub>r</sub>	J <sub>2</sub> / <sub>Toct</sub>	He	J <sub>2</sub> / t <sub>oct</sub>		₹d	u <sub>t</sub>
0.300 S.T. (Chamed) 42.0 76.84 11.6 73.48 5.0 kPs 1.890 40 0.090 spnair Concrete 886.0 - 6676 0.7 2.320 40 0.000 S.T. (Chamed) 55.7 153.19 51.6 102.08 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 46.7 66.95 50.5 91.32 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 56.41 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 56.41 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 56.41 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 56.41 10.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.30 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.3.0 13.0 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .35 0.624 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs 1.890 .40 0.20 S.T. (Chamed) 47.0 61.40 46.0 7 10.5 kPs												(IIPa)			(lig/m <sup>3</sup> )	
0.624 S.T. (Chamed) 72.9 618.73 65.1 344.13 10.0 kPa 1.850 .35 0.500 8.T. (Chamed) 65.1 150.74 60.7 103.90 15.0 kPa 1.850 .35 0.500 8.T. (Chamed) 65.1 150.74 60.7 103.90 15.0 kPa 1.850 .35 0.500 8.T. (Chamed) 65.1 150.74 60.7 103.90 15.0 kPa 1.850 .35 0.500 8.T. (Chamed) 84.3 577.71 15.7 329.82 15.0 kPa 1.850 .35 1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .35 0.500 8.T. (Chamed) 84.3 577.71 15.7 329.82 15.0 kPa 1.850 .35 1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .35 0.500 8.T. (Chamed) 84.3 577.71 15.7 329.82 15.0 kPa 1.850 .35 1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .35 0.500 8.T. (Chamed) 84.3 577.71 15.7 329.82 15.0 kPa 1.850 .35 1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .35 1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .35 1.324 Subgrade 128.7 180.23 180.0 kPa 1.850 .40 0.250 8.T. (Chamed) 84.4 107.99 50.9 130.97 8.0 kPa 1.850 .40 0.250 8.T. (Chamed) 84.4 107.99 50.9 130.97 8.0 kPa 1.850 .40 0.300 8.T. (Chamed) 84.2 78.53 42.0 77.13 5.0 kPa 1.850 .40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.97 8.0 kPa 1.850 .35 0.40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.99 12.0 kPa 1.850 .35 0.40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.99 12.0 kPa 1.850 .35 0.40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.99 12.0 kPa 1.850 .35 0.40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.99 12.0 kPa 1.850 .35 0.40 0.300 8.T. (Chamed) 77.0 596.03 68.9 130.99 12.0 kPa 1.850 .35 0.35 0.35 0.35 0.35 0.35 0.35 0.3	0.300 S.T. (thewed) 0.300 S.T. (thewed)	42.0 55.7	76.84 153.19	11.6 51.6	73.68 102.06	5.0 kPe 10.0 kPe	1.850	.40	0.250 S.T. (thawed)	46.7	60.95	50.5	91.32	10.0 kPa	1.850	.35
1.324 Subgrade 128.7 178.67 126.6 170.43 1.055 .55  3 April 1979 (Day 93)  Plate Pressure (kPe): 235.9 562.5 T(°C)  OF  Thickness (MPe) (kPe)	1.524 Subgrade	128.8		126.1		10.0 kPa	1.055	. 35	0.300 S.T. (thawed) 0.624 S.T. (thawed)	65.1	150.74	60.7	103.90	15.0 kPa	1.850	. 35
Plate Pressure (kPe): 235.9		200.0	_	200.0	_	_	1.033	.35	1.524 Subgrade	128.7		126.6			1.055	. 35
Trickness		25.5	<b></b>	•	2.5											
No.   1/2   Tock   No.																
0.250 8.T. (thered) 44.4 107.99 50.9 130.97 6.0 kPs 1.850 .40 0.300 8.T. (thered) 42.2 78.53 42.0 77.13 5.0 kPs 1.850 .40 0.300 8.T. (thered) 59.0 148.42 54.7 100.70 12.0 kPs 1.850 .35 0.824 8.T. (thered) 77.0 596.03 48.9 12.0 kPs 1.850 .35 1.524 Subgrads 128.7 180.23 126.6 170.46 — 1.055 .35  - Subgrads 200.0 — 200.0 — 1.055 .35  - Tangential Strain c <sub>s</sub> (r = 0, s = .05) and Vertical Strain c <sub>s</sub> (r = 0, s = 1.524)  - 30.0ct 12 Peb 6 Mar 12 Mar 20 Mar 27 Mar 3 Apr 23 Apr 8 May 30 May 24 Jul 27 Sap 19 Nov																
0.300 S.T. (thered) 42.2 78.53 42.0 77.13 5.0 MPa 1.850 .40 0.300 S.T. (thered) 59.0 149.42 54.7 100.70 12.0 MPa 1.850 .35 0.624 S.T. (thered) 77.0 596.03 68.9 334.99 12.0 MPa 1.850 .35 1.524 Subgrade 128.7 180.23 126.6 170.46 — 1.055 .35  - Subgrade 200.0 — 200.0 — 1.055 .35  - Tangential Strain c <sub>2</sub> (r = 0, s = .05) and Vertical Strain c <sub>3</sub> (r = 0, s = 1.524)  - 30.0ct 12 Peb 6 Mar 12 Mer 20 Mer 27 Max 3 Apr 23 Apr 8 May 30 May 24 Jul 27 Sap 19 Nov	0.050 Asphalt Concrete		107.00		130 47		2.320	.45								
0.624 S.T. (thoused) 77.0 596.03 68.9 334.99 12.0 MPa 1.850 .35 1.524 Subgrada 128.7 180.23 126.6 170.46 — 1.055 .35  — Subgrada 200.0 — 200.0 — 1.055 .35  Tangential Strain c <sub>s</sub> (r = 0, s = .05) and Vertical Strain c <sub>y</sub> (r = 0, s = 1.524)  30.0ct 12 Peb 6 Mar 12 Mer 20 Mer 27 Max 3 Apr 23 Apr 8 May 30 May 24 Jul 27 Sep 19 Nov	0.300 S.T. (thoused)	42.2	78.53	42.0	77.13	5.0 kPa	1.850	.40								
- Subgrade 200.0 200.0 1.055 .35  Tangential Strain co (r = 0, s = .05) and Vertical Strain co (r = 0, s = 1.524)  30 Oct 12 Feb 6 Mar 12 Mar 20 Mar 27 Max 3 Apr 23 Apr 8 May 30 May 24 Jul 27 Sep 19 Nov	0.624 S.T. (thouse)	77.0	596.03	68.9	334.99	12.0 kPa	1.850	. 35								
30 Oct 12 Peb 6 Mar 12 Mar 20 Mar 27 Mar 3 Apr 23 Apr 8 May 30 May 24 Jul 27 Bap 19 Nov						-										
				<u>14</u>	agential S	troto e (	r = 0,	03	and Vertical Strain cy (r = 0,	1.	524)					
	- /lan	_								_						

20 Mor 27 Mor 3. Apr 23 Apr 4.789x10<sup>-4</sup> 4.350x10<sup>-4</sup> 4.3

Table D6b. Resilient moduli and supporting data calculated by NELAPAV for Sibley till test section, 1980.

25 February 1980 (Day 50	<u>6)</u>							29 March 1980 (Day 89)							
Plate Pressure (kPa):	300.0		575.0					Plate Pressure (kPa):	258.0		505.0				
					T(*C)								T(*C)		
Thickness	Hr	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>	•	Ya .	Ψr	Thickness	ĸ <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>	Hr	J <sub>2</sub> / <sub>Toct</sub>		Υd	ν,
(m) Materials	(HPa)	(kPa)	(MPa)	(kPa)	(EPa)	(Mg/m 3		(m) Materials	(MPa)	(kfa)	(MPs)	(kPa)	(kJa)	(Hg/m <sup>3</sup>	<u> </u>
0.050 Asphalt Concrete 0.250 S.T. (frozen)	9798.0 3449.0		9798.0 3449.0	_	3.2° ~0.7°	2.320 1.890	.40	0.050 Asphalt Concrete			5471.0	_	11.0*	2.320	
0.300 S.T. (frosen)	2775.0		2775.0	_	~0.5°	1.890	.35	0.250 S.T. (thewad) 0.300 S.T. (thewad)	39.7 37.0	121.22 84.22	43.2 36.9	188.06 88.23	0.0 kPa 0.0 kPa		
0.300 S.T. (frozen) 0.624 S.T. (frozen)	3122.0 591.0	_	3122.0 591.0	=	~0.6°	1.890		0.300 S.T. (thawed)	43.2	188.01	41.1	144.84	0.0 kPa	1.900	.45
1.524 Subgrade	131.0	187.85	129.3	161.05	-	1.055	.35	0.624 S.T. (thawed) 1.524 Subgrade	57.1 129.3	695.58 181.01	52.4 127.7	443.71 174.75	1.0 kPa	1.900	
<ul> <li>Subgrade</li> </ul>	200.0	-	200.0	-		1.055	.35	- Subgrade	200.0	~	200.0			1.055	
12 March 1980 (Day 72)															
Plate Pressure (kPa):	273.0		600.0		T(*C)			3 April 1980 (Day 94)							
					or			Plate Pressure (kPa):	26	5.0	51	6.0	****		
Thickness	H <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / Toct	•	Ya	"r						or 0r		
(m) Materials	(HPs)	(kPa)	(MPa)	(kPa)	(kPa)	$(Hg/m^3)$	)	Thickness	H <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>		ď	<b>"</b> r
0.050 1	1010.0							(m) Materials	(MPa)		(MPs)	(kPa)	(kPa)	(Mg/m <sup>3</sup>	
0.050 Asphalt Concrete 0.250 S.T. (thewed)	40.2	128.51	4058.0 44.6	220.61	15.0° 0.0 kPa	2.320	.45	0.050 Asphalt Concrete							
0.300 S.T. (thawed)	37.9	82.58	38.2	85.00	1.0 kPa	1.900	.45	0.250 S.T. (thawed)	3823.0 40.7	119.70	3823.0 44.3	185.79	15.8° 1.0 kPa	2.320	.50
0.300 S.T. (thawed) 0.624 S.T. (thawed)	45.5 62.1	183.57 591.77	43.3 56.0	141.20 345.82	2.0 kPa 5.0 kPa			0.300 S.T. (thawed)	36.6	80.18	36.8	80.94	0.0 kPa		
1.524 Subgrade	128.4	177-54	125.8	167.52		1.055	.35	0.300 S.T. (thawed) 0.624 S.T. (thawed)	44.0 58.3	179.21 667.08	41.9 53.5	139.19		1.900	-45
<ul> <li>Subgrade</li> </ul>	200.0		200.0	-	-	1.055	.35	1.524 Subgrade	129.2	180.62	125.5	428.67 166.50	2.0 kPa	1.900	.45
19 March 1980 (Day 79)								- Subgrade	200.0		200.0			1.055	.35
Plate Pressure (kPa):	254	0	36	0.0				10 April 1980 (Day 101)							
					T(*C)			Fiste Pressure (kPa):	248	.0	50				
	H <sub>r</sub>	J <sub>2</sub> /t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / <sub>oct</sub>	•	Ya	μ						T(*C)		
Thickness (m) Materials	(MPa)	(kPa)	(MPa)	(kPa)	(kPa)	$(Hg/m^3)$	)	Thickness	M <sub>E</sub>	J <sub>2</sub> / t <sub>oct</sub>	Ħŗ	J <sub>2</sub> / t <sub>oct</sub>	•	Yd	μr
								(m) Materials	(HPa)	(kPa)	(MPa)	(kPa)	(kPa)	(Hg/m <sup>3</sup> )	
0.050 Asphalt Concrete 0.250 S.T. (thawed)	39.4	115.96	2217.0 41.1	145.00	20.0° 0.0 kPa	1.900		0.050 Asphalt Concrete		-					
U.300 S.T. (thawed)	36.3	75.44	36.1	73.73	0.0 kPa	1.900	.45	0.250 S.T. (thawed)	39.6	119.00	6876.0 43.2	188.39	16.0° 0.0 kPa	2.320	.40
0.300 S.T. (thawed) 0.624 S.T. (thawed)	42.8 58.4	178.56 673.64	41.6 55.7	153.91 526.25	0.0 kPa 2.0 kPa	1.900	.45	0.300 S.T. (thewed) 0.300 S.T. (thewed)	37.3	86.96	37.1	85.55	0.0 kPa		.45
1.524 Subgrade	128.8	178.97	128.3	177.00		1.055	.35	0.624 S.T. (thewed)	43.5 57.6	195.55 723.76	41.2 52.5	147.41 448.52	0.0 kPa 1.0 kPa		.45
<ul> <li>Subgrade</li> </ul>	200.0		200.0			1.055	.35	1.524 Subgrade - Subgrade	129.4	181.45	125.7	167.32	-	1.055	.45
22 March 1980 (Day 82)								17 April 1980 (Day 108)	200.0		200.0	-		1.055	. 35
			330.0												
Plate Pressure (kPa):	167	167.0		330.0		T(*C)		Plate Pressure (kPa):	240.0		455.0		T(*C)		
	H <sub>E</sub>	J <sub>2</sub> / <sub>Toct</sub>	H <sub>r</sub>	J <sub>2</sub> / Toct	or *	Y <sub>4</sub>	u <sub>e</sub>		H <sub>r</sub>	J <sub>2</sub> / t <sub>oct</sub>	H <sub>r</sub>	J <sub>2</sub> / †oct	or •	ν.	
Thickness Materials	(IEa)	( <b>EPa</b> )	(MPa)	(kPa)	(kPa)	(Mg/m <sup>3</sup> )		Thickness (m) Meterials	(ICPs)	(k)a)	r (HPa)	4 oct (kPa)		<sup>Y</sup> d (Ng/=³)	u <sub>t</sub>
0.050 Asphalt Concrete	5988.0		5988.0		8.0*	2.320		0.050 Asphelt Concrete			5988.0	<u>,</u>			
0.250 S.T. (thewed)	37.9	95.18	40.9	141.37	O.O kPa	1.900	.45	0.250 S.T. (thawed)	42.3	68.71	45.3	97.55	8.0° 6.0 kPa	1.850	.45
0.300 S.T. (thawed) 0.300 S.T. (thawed)	37.6 45.2	91.30 237.70	36.9 42.2	82.79 167.22	0.0 kPa	1.900	.45	0.300 S.T. (thawad) 0.300 S.T. (thawad)	37.3 43.8	87.69 201.77	37.2	85-67	0.0 kPa	1.900	.45
0.624 S.T. (thewed)	59.4	984.36	53.8	588.72	0.0 kPa	1.900	.45	0.624 S.T. (thawad)	59.5	742.63	41.6 54.7	154.91 476.65	0.0 kPa 2.0 kPa	1.900	.45
1.524 Subgrade - Subgrade	130.2 200.0	184.56	128.6	178.51	_	1.055		1.524 Subgrade - Subgrade	128.9	179.48	127.5	174.20		1.055	. 35
26 March 1980 (Day 86)								•			100.0			1.055	. 35
Plate Pressure (kPa):	24	6.0													
					7(°E)										
	Hr	J <sub>2</sub> / <sub>Toct</sub>	×r	J <sub>2</sub> / t <sub>oct</sub>	or *	Y <sub>d</sub>	n <sup>E</sup>								
Thickness (m) Materials	(107a)	2' 'oct (kPa)		2' oct (kPa)											
			(MPa)		(kPa)	(Hg/m <sup>3</sup> )									
0.050 Asphalt Concrete 0.250 S.T. (thewad)	39.5	117.33	=	=	12.5° 0.0 kPa		.45								
0.300 \$.T. (thornd) 0.300 \$.T. (thornd)	36.9	83.02	-		0.0 kPa	1.900	.45								
0.300 S.T. (thursd) 0.624 S.T. (thursd)	43.2 55.9	188.84 721.60	_	-	0.0 kPa 0.0 kPa		.45								
1.524 Subgrade	129.4	181.42	=======================================	=	_	1.055	. 35								
- Subgrade	200.0	-	-		-	1.055	.35								

#### Tangential Strain $\epsilon_k$ (r = 0, z = .05) and Vertical Strain $\epsilon_k$ (r = 0, z = 1.524)

25 Feb 12 Mar 19 Mar 22 Mar 26 Mar 29 Mar 3 Apr c<sub>E</sub>(low pressure): 8.156x10<sup>-6</sup> 4.214x10<sup>-6</sup> 5.321x10<sup>-6</sup> 2.151x10<sup>-6</sup> 3.444x10<sup>-6</sup> 3.373x10<sup>-6</sup> 4.222x10<sup>-6</sup> 2.906x10<sup>-6</sup> 2.913x10<sup>-6</sup> /(high pressure): 1.568x10<sup>-5</sup> 8.937x10<sup>-4</sup> 7.411x10<sup>-4</sup> 4.171x10<sup>-4</sup> -- 6.445x10<sup>-4</sup> 7.984x10<sup>-4</sup> 5.771x10<sup>-4</sup> 5.416x10<sup>-4</sup> r<sub>v</sub>(low pressure): -1.668x10<sup>-4</sup>-2.064x10<sup>-4</sup>-2.072x10<sup>-4</sup>-1.878x10<sup>-4</sup>-2.046x10<sup>-4</sup>-2.069x10<sup>-4</sup>-2.090x10<sup>-4</sup>-2.044x10<sup>-4</sup>-2.012x10<sup>-4</sup> (high pressure): -1.792x10<sup>-4</sup>-2.172x10<sup>-4</sup>-2.304x10<sup>-4</sup>-2.217x10<sup>-6</sup> -- -2.588x10<sup>-4</sup>-2.599x10<sup>-4</sup>-2.553x10<sup>-4</sup>-2.454x10<sup>-6</sup> \* Notes: (1) Modult, stresses, and strains calculated by MELAPAV

■ おいことという。 最大な人人な人ななななななななななななな。 またいとうしゅう はっしょうしょうしょ はまた ちゃく なん Company of the production of the production of the product of the product

- (2)  $M_{\chi}$  = resilient modulus,  $J_1$  = first stress invertent or bulk stress,  $\phi$  = moisture tension,  $\gamma_d$  = dry unit weight,  $\mu_{\chi}$  = resilient Poisson's ratio
- (3)  $H_{\mbox{\scriptsize T}}$  and  $J_{\mbox{\scriptsize L}}$  are calculated at r=0 and center of respective layer
- (4) S.T. refers to Sibley till (never fromes except at noted).
- (5) Yoct = octahedral shear etress (kPs)
- (6) Negative normal stresses and strains are compressive.

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Johnson, T.C.

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1. Asphalt concrete. 2. Elastic layered system analysis. 3. Falling weight deflectometer tests. 4. Frost action. 5. Granular soil. 6. Moisture tension. 7. Nonlinear materials characterizations. 8. Pavement design. 9. Repeated-load plate-bearing tests. 10. Repeated load triaxial tests. 11. Resilient modulus. 12. Seasonal change in modulus. 13. Thaw weakening.

14. Unbound base course.

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